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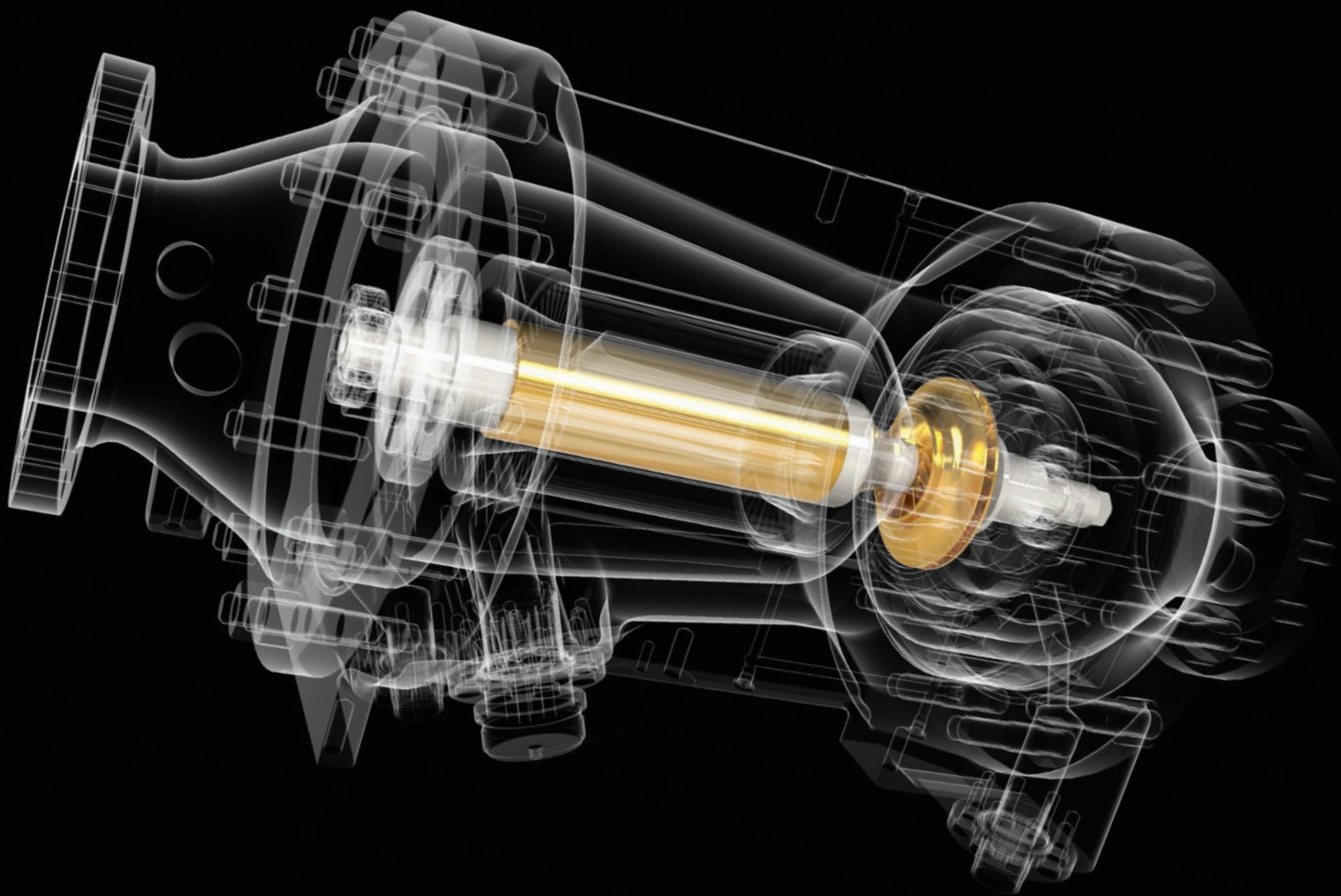
An Inside Look at EXPANDERS

page 28



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Cover Story

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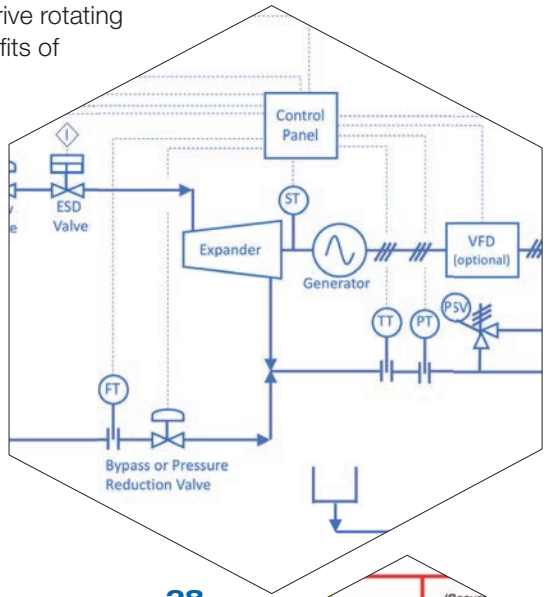
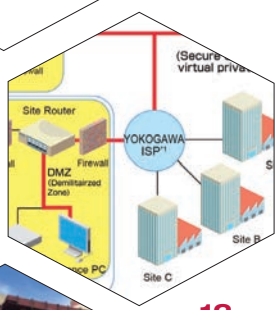
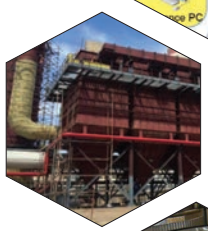


28



12



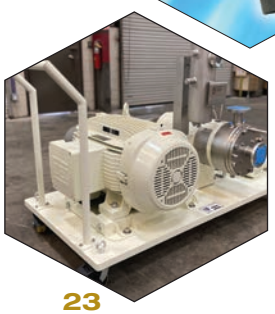
40

46

Technical and Practical

50

16



23

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Cover design: Tara Bekman; **Cover image:** A three-dimensional rendering of a FreeSpin In-Line Turboexpander created by Sapphire Technologies

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Editor's Page

Feeling video fatigue?

It has been a full year since our world was changed by the coronavirus pandemic. The disruptions to our lives have been many, and the one perhaps most invasive to our day-to-day routines has been the need for social distancing. All of our social contact, both for business and personal interactions, was swiftly and severely changed. Few of us knew that the dinner we had in a restaurant with friends, or the business meeting we attended last March would be our last for quite a while. Many of us who can, have been working from home. And many, if not most of us, are spending quite a few hours on videoconferences.

We are each probably familiar with at least a half dozen different platforms now. Videoconferencing is so ubiquitous that the most referred-to platform has given the word "zooming" new meaning in our lexicon. Videoconferencing has a lot of perks. I have been able to virtually attend a wider variety of conferences, lectures, social gatherings and more, than I would have been able to attend in person. And, with the rather harsh winter this year, weather-related travel concerns were not an issue. And I don't think it is a bad thing to occasionally see a colleague's family member or the family dog or cat on screen. It can, however, be difficult to spend many hours in the two-dimensional world of videoconferencing. Many complain of fatigue.

Videoconference fatigue

Researchers at Stanford University examined why videoconferencing causes fatigue. Led by professor Jeremy Bailenson, their study [*1*] outlined several reasons for videoconference fatigue:

The intensity of excessive close eye contact — constantly looking at people's faces rather than moving our gaze to other things in a room, or to taking notes can be stressful. The authors suggest reducing the size of the onscreen window or moving the screen further away to create more personal space between yourself and the video screen.

Watching yourself on screen — it is unnatural for us to see ourselves during a meeting and can be stressful if we are critical about our own image. A suggestion is to turn off the self-view option.

Lack of mobility — we typically sit in one spot in front of the video camera, which limits our movement more that if we were meeting in person, and interpreting gestures may be more difficult onscreen than in person. The researchers suggest trying to create more distance between yourself and the screen as well as occasionally turning the camera off to take a break from the intensity of the video contact.

Another study [*2*] by researchers at Old Dominion University and Ohio State University uncovered some interesting results that point to less obvious factors that influence videoconference fatigue. They found that time of day of a meeting was more important than the length or number of meetings when it comes to fatigue. Videoconferences held late in the day were more tiring than those held earlier, such as right after lunch. The study also found that using the mute button to relieve anxiety about making unintentional noises during a videoconference was more important than factors around the video screen. And when participants had a sense of connection with others in the group — a sense of belonging — they tired less. ■

Dorothy Lozowski, Editorial Director

1. Stanford researchers identify four causes of 'Zoom fatigue' and their simple fixes, news.stanford.edu/2021/02/23/four-causes-zoom-fatigue-solutions/, February 23, 2021

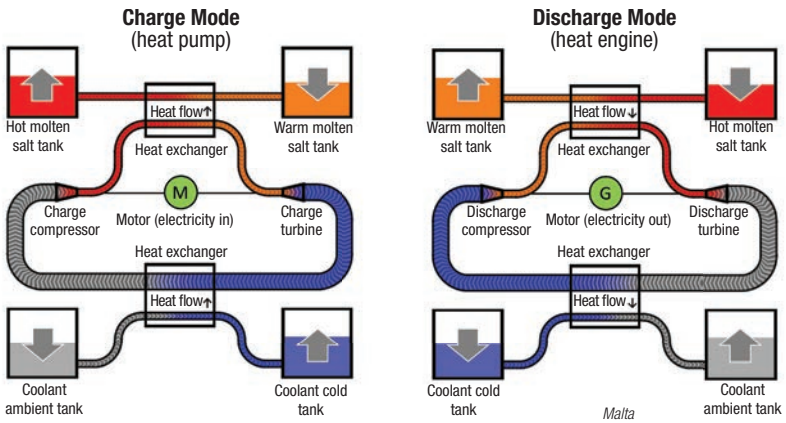
2. Old Dominion University Researchers Co-Author Study on Reducing Videoconference Fatigue, www.odu.edu/news/2021/3/zoom_fatigue#.YFUrAuYpBE4, March 12, 2021

Edited by:
Gerald Ondrey

Thermal-energy storage system can decarbonize industrial heat

A closed-loop, long-duration energy-storage system (diagram) developed by Malta, Inc. (Cambridge, Mass.; www.maltainc.com) could provide a carbon-neutral path to industrial heating. "One of the exciting facets of this technology is that it generates a lot of discharge heat. When we charge our system with renewable energy, the heat we're discharging is, in effect, decarbonized, usable heat," says Ty Jagerson, vice president of commercialization at Malta. Take, for example, Malta's 100-MW M100 system, which is designed for 10 h of charging and discharging per day. "During the discharge cycle, the system is generating 100 MW of electricity, while also generating 70 MW of 100°C heat — over 10 h, that's 700 MWh of usable industrial heat," notes Jagerson. Industrial drying applications — for instance, drying biosolids in wastewater-treatment applications or residues from agricultural or pulp-and-paper processing — are particularly well-suited to efficiently utilize the generated heat. "In that 100°C range, there's a massive amount of heat demand that we could take care of basically by using leftover wind and solar power," he adds.

Malta's thermal storage system incorporates a novel heat-exchanger design co-developed by Alfa Laval AB (Lund, Sweden), one of Malta's major investors. In charging (heat pump) operation, renewable energy runs a charging turbine, which sends hot air through a compressor into a heat exchanger, transferring the air's thermal energy to molten salt, which is subsequently stored in a hot tank, while the cooled media flows between a pair of coolant tanks. When the energy stored in the molten salt needs to be discharged, the temperature difference between the system's tanks is converted to thermal energy, and hot air runs through a second turbine, sending electricity back to the grid. "The system is based on a closed-loop Brayton cycle. When we're charging the system, the air flows in one direction, and then we change the direction of airflow when we are discharging," explains Jagerson. Current designs are focused on 10–12 h of storage, but Malta is seeing increased interest in storage durations as high as 5–7 days.



Malta

Recycling electrolyte from vanadium RFBs

U.S. Vanadium LLC (Hot Springs, Ark.; www.usvanadium.com) has successfully demonstrated the ability to recycle the liquid electrolyte used in vanadium redox-flow batteries (VRFB), a rapidly growing commercial technology that promises to enable intermittent renewable energy technologies, such as solar and wind, to provide power on a continuous basis (see Redox Flow Batteries Charge Forward, *Chem. Eng.* September 2016, pp. 14–20).

Against a background of increasingly prevalent waste-disposal issues faced by lithium-ion batteries, VRFBs have the important benefit of its liquid electrolyte being nearly 100% recyclable. Vanadium electrolyte, and its ability to be recycled for continuing use, is considered to be a key advantage for the technology that is expected to lead to increased worldwide adoption of VRFBs as an alternative to Li-ion batteries.

U.S. Vanadium recently demonstrated the technical and economic feasibility of recycling VRFB electrolyte provided by Invinity Energy Systems plc (Vancouver, B.C., Canada;). The VRFB electrolyte recycling initiative at U.S. Vanadium, where a vanadium recovery rate of 97% was achieved, was led by Mike Woolery, vanadium technologist for U.S. Vanadium. A description of the recycling process and other recycling options can be found at the company's website in a March 8th blog post.

L-ALANINE

DMC Biotechnologies, Inc. (DMC; Boulder, Colo.; www.dmcbio.com) has successfully demonstrated full commercial scale (85 m^3) fermentation for its first product, the amino acid L-alanine. The scaleup results identically tracked the performance at bench and pilot scales, further validating the predictability and scalability of DMC's Dynamic Metabolic Control technology, the company says. Commercial performance metrics were demonstrated, meaning that no further strain improvements are required to achieve the target selling price.

This demonstration of process robustness and predictability across scale of production — from high-throughput screening to full commercial scale — has never been demonstrated in the field and represents a major advancement for DMC. This core technology enablement will also be beneficial for DMC's pipeline of products that will be scaled and commercialized next.

The scale-up process was conducted at the Leuna facility of EW Biotech GmbH (Leuna, Germany; www.ew-biotech.com).

UF MEMBRANE

Toray Industries, Inc. (Tokyo, Japan; www.toray.com) has developed a new polyvinylidene fluoride (PVDF) ultrafiltration (UF) membrane that has an "exceptional" virus removal rate, as well as a high water permeability, making it suitable for water purification. The company is accelerating application testing, with the aim to commercialize the technology.

Toray improved its PVDF

(Continues on p. 6)

UF-membrane technology to enhance pathogenic virus removal and water permeability without reducing safety or increasing costs.

In developing the improved PVDF UF-membrane, the challenge was to reduce pore diameters to remove viruses, without the resulting decrease in water permeability.

Toray used phase-separation control technology to create a uniformly dense structure. By laminating layers that have homogeneous pore-size distribution, Toray created a uniform dense structure without coarse voids (exceeding 100 nm) through which viruses can pass. This uniform dense structure made it possible to create a thinner dense structure than conventional UF membrane, and showed 99.99% removal of the *Essherichia coli* phage MS2, which has a diameter of around 27 nm.

Because the dense structure increases resistance and impedes water flow, the company used a proprietary hollow-fiber membrane process technology to create a thin, uniformly dense structure. Excellent virus removal and water permeability was achieved by increasing the porosity in the bulk of the membrane, except for the uniform dense structure. This led to more water channels and boosted the overall membrane permeability.

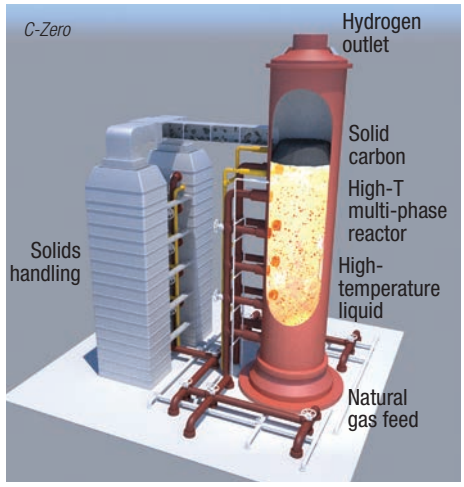
GRAPHENE PLATES

Later this month, Applied Graphene Materials UK Ltd (AGM; Redcar, Cleveland, U.K.; www.appliedgraphenematerials.com) will be presenting its "breakthrough" technology that enables easy graphene dispersion in water-based epoxy coatings, while delivering improved corrosion protection, at the Corrosion 21 Confer-

(Continues on p. 8)

Methane-pyrolysis process leverages natural gas for CO_2-free H_2 generation

Engineering design of a demonstration plant is underway for a process that pyrolyzes natural gas into hydrogen and solid carbon. The process was developed by C-Zero Inc. (Goleta, Calif.; www.czero.energy), a company set up in 2018 to develop and commercialize methane pyrolysis (thermal decomposition without combustion), a process known for decades and investigated recently at the University of California-Santa Barbara (www.ucsb.edu) using high-temperature molten metal and molten salt catalysts. Construction of the plant is slated to begin by the end of 2021.



"C-Zero's technology leverages abundant natural gas as a source of low-cost hydrogen while avoiding the CO_2 emissions usually associated with fossil fuel resources," says Eric McFarland, C-Zero chief technology officer. The process is designed to replace steam-methane reforming (SMR) for hydrogen generation in applications such as ammonia production and petroleum refining, as well as to produce emissions-free H_2 for electric power generation and fuel cells.

The C-Zero process is carried out in a uniquely configured reactor (figure) using the company's high-temperature liquid media as a pyrolysis catalyst. "A main challenge in pyrolysis is establishing an effective way to introduce heat into the reactor, which required an innovative design," McFarland explains. In addition, the process required innovations in materials of construction, heat exchange and an efficient method to remove solid carbon, he says. "While the chemistry is seemingly simple, the details of designing a cost-efficient process are challenging," McFarland adds.

The H_2 purity is matched to the requirements of the application, and the pyrolysis reaction is tolerant of the contaminants usually encountered with natural gas, McFarland points out.

McFarland says capital expenditures for the process should be lower than those for SMR, and the operational cost is already competitive with SMR if an effective cost of $35–60/ton of CO_2 is assigned in a cap-and-trade or carbon-tax scheme. The solid carbon can be sequestered permanently at low cost in abandoned coal mines, he notes.

In February, C-Zero announced investments from Breakthrough Ventures, AP Ventures, Eni S.p.A. and Mitsubishi Heavy Industries Ltd.

New crushing station makes its commercial debut in Brazil

Last month, Amarillo Gold Corp. (Toronto, Canada; www.amarillogold.com) selected Metso Outotec's (Helsinki, Finland; www.mogroup.com) modular FIT Station for its Posse Gold greenfield mining project in the state of Goiás in central Brazil. This will be the first commercial installation of the new crushing and screening system, which was first introduced to the markets last year.

FIT Stations are focused on flexibility and speed for quick installation with two solutions: Jaw stations and Re-crushing stations. The capacities range from 200 up to 3,000 ton/h and both can be used in unique applications with multiple equipment configurations available for flexibility. When comparing the FIT Stations to similar crushing and screening plants in mining, Metso Outotec has seen delivery-time reduction by up to 25% and erection time reduction by up to 15%. With both the Jaw and Re-crushing station options, most of the steel-structure modules can be supplied in containers, for quick delivery and reduced welding time needed on site for the steel structures. Re-crushing stations can handle capacities up to 750 ton/h, and are applied in secondary or tertiary stockpile re-crushing applications. Re-crushing stations involve the company's HP Series cone crushers.

When placed as a supplementary plant for reprocessing plants, the Re-crushing stations will increase semi-autogenous-grinding (SAG) mill capacity by up to 15%, says the company. The Jaw stations have capacities up to 3,000 ton/h.

The FIT Station to be delivered to the Posse Gold project has a design capacity of 540 ton/h of run-of-mine (ROM), with an average production of 102.000 oz of gold/yr (years 1 to 4). The station consists of crushers, vibrating feeders and screens, as well as conveyors and related structures and other equipment.

ence & Expo on April 28th (a virtual event; www.nacecorrosion.org). The technology is said to represent a major milestone in the development of performance-enhancing graphene technologies for more sustainable coatings manufacturers.

AGM has previously demonstrated significant uplifts in anti-corrosion performance in solvent-based coatings through the use of its Genable graphene-nanoplatelet dispersion technology. However, water-based coating development remains a key focus for industry formulators looking to improve the safety and environmental impacts of their products.

To date, dispersion of graphene in water-based systems has been problematic, causing coating instability or requiring large amounts of surfactant. AGM's technology enables easy dispersion of graphene in water-based epoxy coatings, while delivering improved corrosion protection — the research is said to represent an important development in raising waterborne coating anti-corrosion performance in industry applications.

SULFONAMIDES

Sulfonamides are used in many drugs, including antibiotics and Viagra, as well as in agrochemicals and dyes. While to date it has been necessary to use corrosive chemicals, high temperatures and expensive metal catalysts

(Continues on p. 9)

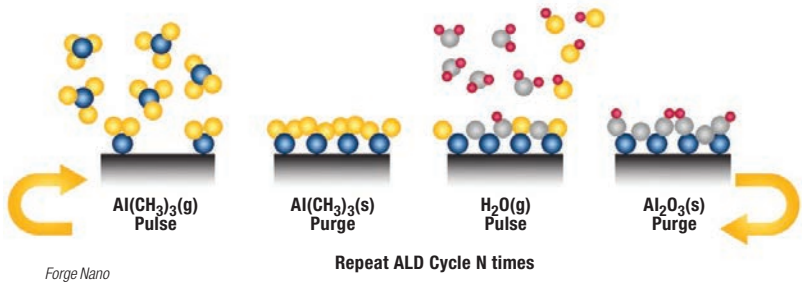
Engineering catalysts with ALD

Atomic-layer deposition (ALD), a surface engineering technique that applies layers of coatings in a conformal way at single-atom thicknesses, is being investigated for its potential to improve the selectivity and durability of industrial catalysts under a U.S. Dept. of Energy grant awarded earlier this year to Forge Nano Inc. (Thornton, Colo.; www.forgenano.com). The grant will advance the use of Forge Nano's low-cost ALD techniques for surface engineering of commercial catalyst materials for a range of industrial reactions in food production, petroleum refining and petrochemicals manufacturing.

ALD works by exposing a substrate material to alternating pulses of gaseous "precursor" molecules that react with surfaces in self-limiting ways (diagram). ALD can be used with substances from across the periodic table. In a classic ALD example, a surface with hydroxyl-groups is treated with gaseous trimethylaluminum (TMA; the first precursor). When the surface hydroxyls are completely consumed by the TMA, the reaction stops. In a second step, water (second precursor) is pulsed to replace the methyl groups, leaving a layer of aluminum and regenerating the surface hydroxyl groups for another round of layering, if desired. In this way, single-atom-thick coatings can be applied one layer at a time. "The self-limiting nature of the reactions allows precise control over the formation of the coating," explains Forge Nano applications engineer Staci Moulton.

Based on research from the University of Colorado-Boulder (www.colorado.edu), the company has developed a set of technologies that allow large-scale ALD use in a variety of application areas and production volumes. Among these technologies is a fluidized-bed reactor for ALD-based coating of particles, in which the precursor gases move upward through a bed of solid substrate material, and a continuous vibrating reactor for high-volume production, in which the solid substrate passes through fixed vessels containing the precursor gases.

The grant advances the use of ALD to overcoat catalyst materials. Forge Nano is also developing the use of ALD to deposit active catalyst materials (in the form of nanoparticle "islands") onto a high-surface-area support material, and creating ALD undercoats beneath the active catalyst to extend catalyst lifetime and stability without affecting pore size and shape.



Forge Nano

Direct metal conversion streamlines cathode-material supply chain

As application demands evolve, battery materials have gotten more complex, incorporating not only lithium, but higher nickel, manganese and cobalt content, while also including various dopants like aluminum or zirconium and stabilizing coatings. Processing all of these disparate components into battery cathode-active materials (CAM) often requires numerous complicated steps, from precipitation of metal sulfates to several grinding and regrinding cycles. Nano One Materials Corp. (Vancouver, B.C., Canada; www.nanoone.ca) aims to simplify the CAM supply chain by demonstrating that its single-step aqueous technology (the one-pot process) can be used for direct metal-to-CAM (M2CAM) conversion, eliminating sulfates from the process. "An issue with using traditional metal sulfates is that they are only about 22% metal, so you're shipping a lot of extra weight in sulfates and water that aren't really part of the active material. There's a lot of wasted energy and extra greenhouse-gas emissions," says Stephen Campbell, chief technology officer at Nano One.

In the one-pot process, all components are placed into an aqueous reaction to form a precursor slurry. The slurry is dried and fired, creating CAM nanocrystals. "Normally, when you make CAM in the conventional way, you end up with a polycrystalline agglomerate that is coated on the outside. In the battery, the agglomerates expand and contract, which fractures the particle and fractures the coating, allowing electrolyte into the inner surface of the material, resulting in a loss of stability," explains Campbell. In the one-pot process, since the coating is mixed with the precursor from the beginning, firing yields individually coated crystals. "The coating comes to the surface of each crystal when it is fired, meaning that there is no additional process to put the coating on the crystal. It also means that each individual crystal is protected," Campbell continues. This unique coated nanostructure gives these CAM particles improved durability when compared to traditional CAM particles. The M2CAM adaptation of the one-pot process has been demonstrated at laboratory scale, and Nano One is discussing scaleup with a number of collaborators across the supply chain.

Piezoelectric wood

Researchers at the Swiss Federal Laboratories for Materials Science and Technology (Empa; Dübendorf; www.empa.ch) and ETH Zurich (both Switzerland; www.ethz.ch) have made wood compressible and turned it into a piezoelectric generator. The research, reported last month in the journal *Science Advances*, has the potential for making wood-based bio-sensors or even for generating usable energy. The researchers have also replaced aggressive chemicals by using naturally occurring, wood-degrading fungi (*Ganoderma applanatum*) for the delignification process. The research was performed by professor Ingo Burgert and his team at Empa and ETH Zurich, together with the Empa research groups of Francis Schwarze and Javier Ribera.

Piezoelectric sensors often use materials that are unsuitable for use in biomedical applications, such as lead zirconate titanate (PZT), which cannot be used on human skin due to the lead it contains. Being able to use the natural piezoelectric effect of wood thus offers a number of advantages. Without special treatment, however, wood is not flexible enough and only a very low electrical voltage is generated in the deformation process.

To make the wood elastic, it must first be partially delignified, which results in a white wood elastic sponge, consisting of superimposed thin layers of cellulose. When squeezed together, differently charged areas are displaced against each other and the surface of the material becomes electrically charged.

Burgert's team demonstrated that a $(1.5\ cm)^3$ test cube remained stable after about 600 load cycles. At each compression, the researchers measured a voltage of around 0.63 V, which is sufficient for sensor applications. In further experiments, 30 such wooden blocks under a load equivalent to the body weight of an adult can generate enough electricity to light up a simple LCD display. This opens the possibility of using wooden floors for converting the energy of people walking on it into electricity.

The researchers are already in talks with potential cooperation partners for adapting the technology for industrial applications.

Integrating intelligent technologies for smarter rice mills

Bühler AG (Uzwil, Switzerland; www.buhlergroup.com) is making a major step towards the digitally connected rice mill of the future. The first rollout for integrated rice mills is entering the final stages, with the initial setup using artificial intelligence (AI) and machine learning (ML) technology to connect the sorter, whitener and sensors to transform stand-alone technologies into one smart integrated system that reduces waste, saves energy and consistently provides the best product quality. "Our digitally integrated system is the world's first," says Johannes Wick, CEO Grains & Food at Bühler. The system is currently being tested at Riseria Taverne SA (Torricella-Taverne, Switzerland).

Bühler has defined the three quality parameters essential to the rice market: shine, smoothness and whiteness. These, together with the percentage of broken rice, determine the quality and therefore the price that can be achieved with the final product. The RiceLinePro DROA sensor continuously assesses and keeps track of these characteristics in realtime using complex ML algorithms. This not only standardizes the process, minimizing error and increasing consistency and reliability, but also reduces reliance on labor.

Bühler's new DS-C Optical Sorter is said to be one of the most advanced pieces of equipment in the entire processing line. It provides realtime product-quality alerts that help to optimize the rice yield, as well as adapt downstream processing technology settings. For a typical optical sorter, ejection spikes often result in the loss of good product. Bühler's integrated digital solutions detect these spikes as they happen. Where there is very little contamination, there may be no need to re-sort the product and it can go straight to packing. At an average throughput of 3,500 kg/h and 25 spikes/d, up to 32,000 kg of good product could be lost over a month if the errors are not detected and rectified. The monthly savings from increased visibility could be as high as $15,000.

The digitally connected technology provides mill operators with the insights they need to correctly adjust solution settings. Over time, the intelligent system is capable of adjusting autonomously. ■

to produce sulfonamides, a new electrochemical method — developed by a research team at Johannes Gutenberg University Mainz (JGU; Germany; www.uni-mainz.de) — requires only cheaper starting materials, electrical current and relatively safe solvents. The researchers recently reported their findings in *Angewandte Chemie International Edition*.

"The conventional procedure requires three reaction stages, with each stage driving up manufacturing costs by a factor of two to five. With the new method, just one reaction stage is needed. That makes it readily scalable and it can thus be applied on a technical scale," says professor Siegfried Waldvogel, head of the research team.

The starting materials for the new reaction are amines, aromatics and SO_2, which is a waste product of many industrial processes. In effect, the new method makes it possible to convert this unwanted material into valuable products. The amines react with the SO_2 in solution, producing amidosulfinate as an intermediate product. This makes oxygen and sulfur available to react with the aromatic molecules that have already been oxidized using an electrical current. To prevent oxygen from bonding during this process, a suitable solvent was selected — "that is the really clever bit," Waldvogel points out. The solvent forms strong hydrogen bonds with the oxygen atoms, thereby rendering them inactive — and clearing the way for the formation of the desired S–C bonds. After the reaction, the solvent can be redistilled and used again.

SnS SOLAR CELL

Current thin-film solar cells often use cadmium telluride and copper indium gallium selenide to induce the photovoltaic effect. However, these materials contain rare and toxic elements. To avoid these elements, researchers from Tohoku University (Japan; www.tohoku.ac.jp) have created a tin monosulfide (SnS) solar cell that boasts attractive performance levels. Both Sn and S are abundant, easy to refine and non-toxic. The prototype is described in the February issue of *Solar RRL*. ❐

LINEUP

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Plant Watch

Thermo Fisher Scientific plans $600-million bioprocessing expansion

March 12, 2021 — Thermo Fisher Scientific Inc. (Waltham, Mass.; www.thermofisher.com) plans to invest more than $600 million in capital investments to expand its bioprocessing production capabilities through 2022. These investments are expected to more than double the company's current manufacturing capacity. Highlights of the investment include capacity expansions at several sites in the U.S., China, Scotland and Singapore. Furthermore, the company will open a new resin-manufacturing facility in Chelmsford, Mass.

Hexion to expand Portland manufacturing plant

March 11, 2021 — Hexion Inc. (Columbus, Ohio; www.hexion.com) intends to expand its Portland, Ore., manufacturing site with a second automated manufacturing line to produce fire-resistant protective wrap materials. The new production line is expected to start up around year-end 2021. Hexion's proprietary wrap material can be applied to either new or existing wood utility poles to protect against fire.

BASF doubles acrylic dispersions capacity in Pasir Gudang, Malaysia

March 9, 2021 — BASF SE (Ludwigshafen, Germany; www.basf.com) started up its new acrylic-dispersions production line in Pasir Gudang, Malaysia, doubling production capacity at the site. The new facility will produce acrylic dispersions serving the coatings, construction, adhesives and packaging industries in the Asia-Pacific region.

Solvay completes new high-purity hydrogen peroxide plant in Germany

March 9, 2021 — Solvay S.A. (Brussels, Belgium; www.solvay. com) has built a new electronics-grade production facility for high-purity hydrogen peroxide at its Bernburg site in Germany. The new site accommodates the semiconductor industry's strict requirements for hydrogen peroxide, a key chemical in the manufacture of semiconductor chips.

OMV plans to build glycerin-to-propanol pilot plant

March 4, 2021 — OMV AG (Vienna, Austria; www.omv.com) plans to invest €30 million to build a new pilot plant at its Schwechat Refinery in Austria. The plant will employ a patented process to convert glycerin waste from the production of biodiesel, detergents and soaps into 1.25 million L/yr of bio-based propanol, which will be used as a bio-additive for gasoline. The pilot plant is expected to start up in 2023.

Dow to establish South China Specialties Hub

March 4, 2021 — Dow, Inc. (Midland, Mich.; www.dow.com) will invest approximately $250 million to construct the South China Specialties Hub. The project will involve the construction of specialty polyurethanes and alkoxylates facilities with a total production capacity of approximately 250,000 metric tons per year (m.t./yr). The Dow South China Specialties Hub will be located at Donghai Island in Zhanjiang and will include a include a deepwater port, transportation networks and infrastructure.

Haldor Topsoe to build large-scale SOEC electrolyzer manufacturing facility

March 4, 2021 — Haldor Topsoe A/S (Lyngby, Denmark; www.topsoe.com) will invest in a manufacturing facility for solid-oxide electrolyzer cells (SOEC), predominantly for green hydrogen plants, with a total capacity of 500 MW/yr with the option to expand to 5 GW/yr. Construction will commence in 2022 and the facility will be operational by 2023.

Corbion announces global expansion of lactic acid production

March 3, 2021 — Corbion N.V. (Amsterdam, the Netherlands; www.corbion.com) will substantially increase its global production capacity for lactic acid and lactic-acid derivatives. Existing sites will be expanded in Gorinchem, the Netherlands, Rayong, Thailand, Campos, Brazil and Montmeló, Spain. Corbion previously announced the expansion of lactic acid production at its site in Blair, Neb.

Shell's Rhineland Refinery to expand hydrogen electrolysis capacity tenfold

March 2, 2021 — Shell (The Hague, the Netherlands; www.shell.com) plans to expand the capacity of the hydrogen electrolysis plant being constructed at the Rhineland Refinery in Germany. Electrolysis capacity at the site will be scaled up from 10 to 100 MW. With this added capacity, Rhineland will also commence production of sustainable aviation fuels (SAF) at a 100,000-m.t./yr power-to-liquid plant, which is slated for commissioning in 2025.

Braskem to expand production capacity for biopolymers in Brazil

February 24, 2021 — Braskem S.A. (São Paulo, Brazil; www.braskem.com) is expanding production capacity of sugarcane-derived ethylene, which is used in the production of renewable resins. Production of this raw material at the company's plant in Triunfo, Rio Grande do Sul, Brazil will be increased from 200,000 to 260,000 m.t./yr. The expansion project, budgeted at $61 million, should be concluded in the fourth quarter of 2022.

Mergers & Acquisitions

Clariant and India Glycols form JV for renewable EO derivatives

March 11, 2021 — Clariant AG (Muttenz, Switzerland; www.clariant.com) and India Glycols Ltd. (IGL) plan to establish a joint venture (JV) for renewable ethylene oxide (EO) derivatives. IGL will contribute its Bio-EO Derivative business to the JV, which includes a multipurpose production facility with an alkoxylation plant located in Kashipur, India. Clariant will contribute its Industrial and Consumer Specialties business activities in India, Sri Lanka, Bangladesh and Nepal.

Siemens concludes sale of Flender GmbH to Carlyle Group

March 10, 2021 — Siemens AG (Munich, Germany; www.siemens.com) has successfully closed the sale of Flender GmbH, a specialized supplier of mechanical and electrical drive systems, to The Carlyle Group for €2.025 billion. Flender generated revenue of roughly €2.2 billion in 2020.

DuPont to acquire Laird Performance Materials for $2.3 billion

March 8, 2021 — DuPont (Wilmington, Del.; www.dupont.com) has entered into a definitive agreement with private-equity firm Advent International to acquire Laird Performance Materials for $2.3 billion. The transaction is expected to close in the third quarter of 2021. Laird manufactures a portfolio of heat-management and electromagnetic-shielding products.

Air Liquide to acquire hydrogen and nitrogen production units in Kazakhstan

March 3, 2021 — Air Liquide S.A. (Paris, France; www.airliquide.com) increased its presence in Kazakhstan through its 75%-owned JV Air Liquide Munay Tech Gases (ALMTG). The JV will invest up to €86 million to acquire H_2 and N_2 production units from the Atyrau petroleum refinery owned by KazMunayGas.Under a new longterm agreement, ALMTG will operate these assets to supply industrial gases to the Atyrau refinery. Up to 200 million m^3/yr of H_2 and up to 50 million m^3/yr of N_2 will be produced at the site.

Nouryon sells its Salt Specialties business to Salins Group

March 3, 2021 — Nouryon (Amsterdam, the Netherlands; www.nouryon.com) signed an agreement to divest its Salt Specialties business, including the JOZO, NEZO, Suprasel, Sanal and KNZ brands, to French salt company Salins Group. The acquisition includes three locations for the packing and distribution of specialty salt in Hengelo, the Netherlands, Mariager, Denmark and Gothenburg, Sweden. Nouryon will supply Salins with high-purity vacuum salt from its mining operations near Hengelo and Mariager.

Grace to acquire Albemarle's Fine Chemistry business for $570 million

February 26, 2021 — W. R. Grace & Co. (Columbia, Md.; www.grace.com) has entered into an agreement to acquire the Fine Chemistry Services (FCS) business of Albemarle Corp. (Charlotte, N.C.; www.albemarle.com) for approximately $570 million. The acquisition significantly expands Grace's existing pharmaceuticals portfolio, with capabilities supporting the entire small-molecule development cycle. ■

Mary Page Bailey

Cybersecurity: Continuous Vigilance Required

As digitalization becomes more common and remote operations become necessary, guarding against cybersecurity breaches grows even more critical

The hacking of a Florida water plant, which made headlines in February, was a poignant reminder of the dangers posed by breaches of cybersecurity. Although the incident was discovered before real harm could occur, it highlights the importance of due vigilance when it comes to the security of IT (information technology) and OT (operational technology) of plants in the chemical process industries (CPI).

Threats are always there

"The [CPI] face increasing and more sophisticated cybersecurity threats," says Michael Lester, director of cybersecurity strategy, governance and architecture at Emerson (St. Louis, Mo.; www.emerson.com). "Attacks are constantly evolving, as commoditized malware and advanced technologies provide new capabilities to threat actors. The motivation is still mostly financial gain, but nation state actors are increasingly involved and there are increasing numbers of attacks targeting the industrial control space from various threat actors," he says.

"Smaller chemical facilities often have older 'patchwork' automation systems that increases vulnerability compounded by a lack of resources to routinely assess and strengthen their cybersecurity," Lester says. "Recent attacks are a reminder that regardless of size, industry or location, all facilities need to be aggressive about cybersecurity."

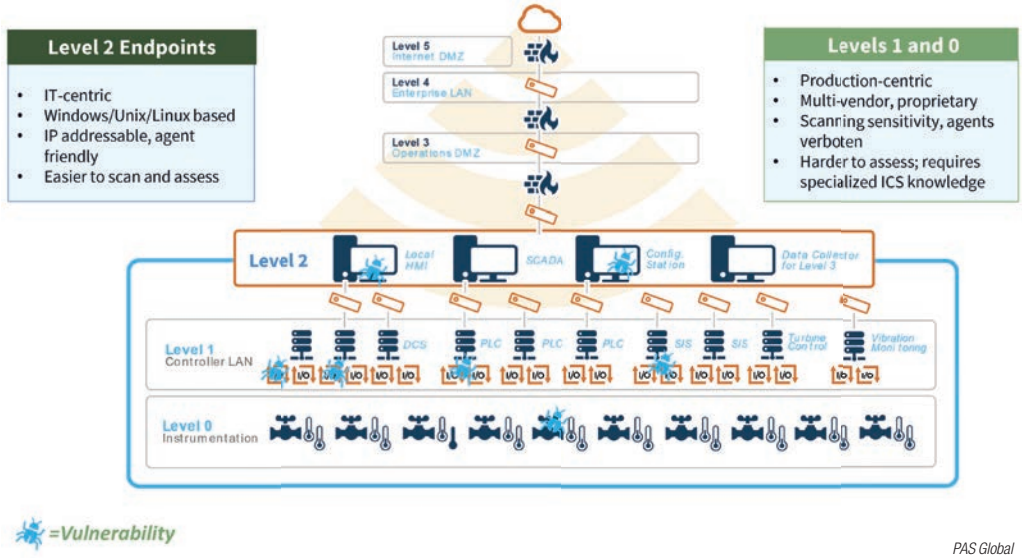
"Cyber-threats to industrial organizations will continue to increase, in both volume and sophistication," echoes Donovan Tindill, senior cybersecurity strategist at Honeywell Process Solutions (Houston; www.honeywellprocess.com). "We've reached a point where cyberattacks are not a question of if, but rather of when and what could be done to prevent that attack or minimize its harm. If you own or manage an OT-based operation, the time to take action and prepare your network is now," he says.

IIoT increases vulnerability

Maintaining a competitive edge means leveraging the industrial internet of things (IIoT) technologies, says Emerson's Lester. "More connections mean more potential vulnerabilities — and organizations need to prioritize cybersecurity equally alongside their IIoT and digital transformation initiatives," he says.

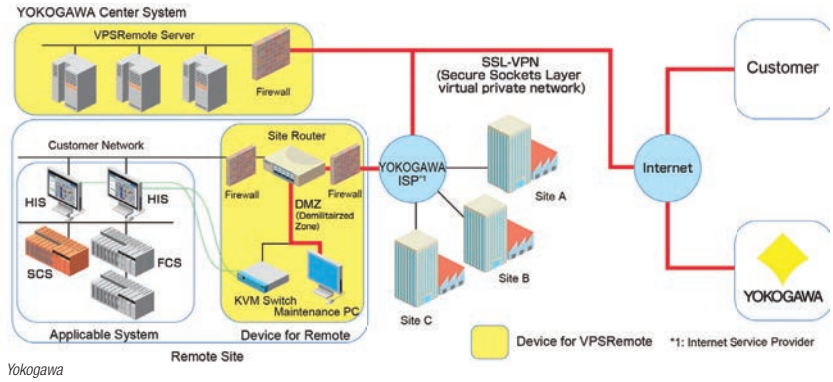
Honeywell's Tindill would agree. "The growth in the number of sensors or cloud connectivity increases the scope of cybersecurity, the attack footprint and the exposure as the number of cyber assets requiring cybersecurity protection and detection increases," says Tindill. "The objective of robust cybersecurity management is to protect the increasing count of cyber assets with basic cyber hygiene, such as strong remote access, electronic security perimeter, patching, monitoring, and incident response to ensure it is not more vulnerable," he says.

"In our experience, it is necessary to audit cybersecurity at least once per year and remediate all risks that exceed the tolerance level for that organiza-



PAS Global

FIGURE 1. Discovering and remediating vulnerabilities in OT is complex



Yokogawa

FIGURE 2. The VPSRemote is configured with devices installed at the user's site for remote operation and linked to the secure Yokogawa Center System, which provides a safe network communication environment to connect these devices and systems

tion," continues Tindill. "Recommendations may include additional network segmentation, application whitelisting, endpoint hardening, security logging, proactive monitoring, robust incident response, and more," he says.

The benefits of due vigilance are real. "If you implement a foundational set of security controls in your plant systems that everyone should have, like patching, endpoint protection, backups and inventory management, then you can reduce your cybersecurity risk by up to 85%," says Ben Dickinson, global product manager — cybersecurity, ABB Energy Industries (Zurich, Switzerland; www.abb.com).

"The proliferation of IIoT devices introduces a new risk that companies must consider as they have the potential to increase the attack surface that hackers can exploit," says Mark Carrigan, chief operating officer, PAS Global, LLC (Houston; www.pas.com; Figure 1). "The reality today is that in most areas, OT cybersecurity trails IT cybersecurity. Many companies are realizing that they must implement the basics of cybersecurity for their OT assets, including collecting a holistic inventory of all assets (hardware, software and firmware), identifying and remediating vulnerabilities and improving the backup and recovery processes to ensure they can minimize the impact of a successful attack," says Carrigan.

To help in these efforts, PAS offers its Cyber Integrity platform (which includes Automation Integrity) to prevent, detect and remediate industrial cyberthreats. PAS Cyber Integrity is said to deliver comprehensive inventory, vulnerability, configuration, compliance, backup and recovery, and risk management for OT assets. In January, PAS launched a new module for Automation Integrity — Sensor Data Integrity — that "improves the discovery and configuration-management of IIoT devices that are prevalent in the process industries," says Carrigan.

Sensor Data Integrity enables industrial organizations to ensure configuration-data integrity for smart and traditional sensors with signal tracing and validation. This addition to Automation Integrity helps reduce both process safety and cyber risk in support of digital transformation initiatives. The new Sensor Data Integrity module provides multi-vendor discovery of smart IIoT and traditional analog sensors; visibility to the complete inventory and potential cyber vulnerability for sensors; creation of templates to define approved configuration for each sensor type; automated detection of configuration errors; automated identification of devices that don't match assigned templates; cross-checking of parameters; support for large-scale, multi-site sensor deployments; and sensor signal tracing, validation and visualization. The information provided by Sensor Data Integrity can also be leveraged by sensor asset-management systems (AMS) to support instrument calibration, and can feed PAS

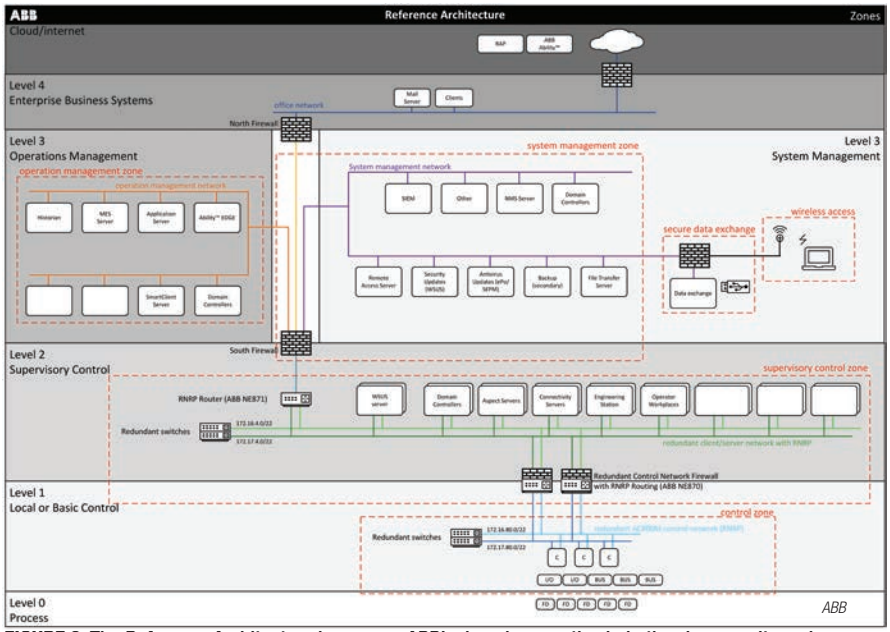


FIGURE 3. The Reference Architecture harnesses ABB's domain expertise in both cybersecurity and control-system technology to define a standardized definition of a secure control system architecture, and using a standard terminology that aligns with international standard IEC62443. This enables ABB to standardize the way in which it designs and implements its control-systems technology to deliver a secure setup by default and using a consistent approach across different delivery teams

Cyber Integrity to support cybersecurity vulnerability assessments.

Security monitoring

Digital transformation typically involves providing more people and more access to data from the industrial control system (ICS) and other OT devices and systems, says Emerson's Lester. "This may include not only manufacturing and production staff members, but also third-party suppliers who assist in optimizing asset and overall performance. This increased data flow requires careful consideration of the architecture and systems and processes to continually monitor this architecture," he says.

"Security monitoring is not only an important mechanism to detect threats, but also helps with forensics and preventing similar future attacks," Lester continues. "A centralized Security Information and Event Management (SIEM) platform can take ICS workstations, servers and network equipment system events and logs and put them into a meaningful dashboard for prompt response from qualified resources. A SIEM can also monitor network traffic data through Network Security Monitoring appliances using a one-way-only communication flow as an added security monitoring feature," he says.

At the forefront of such efforts, LogPoint A/S (Copenhagen, Denmark; www.logpoint.com) launched Version 6.10 of its SIEM solution in February. This latest LogPoint release enables sharing of security analytics and dashboards and provides more context on attack developments supporting the latest MITRE ATT&CK framework. LogPoint 6.10 also integrates with third-party detection-and-response systems to send notifications to Managed Detection and Response (MDR) providers.

Role-based access to dashboards in LogPoint 6.10 helps teams effectively manage and update each other on evolving threats, increasing efficiency in the SOC and decreasing false positives. Configurable role-based, read-write access to each dashboard means that whenever an analyst makes an update, all users with access to the dashboard see the changes, says the company.

Security in the time of pandemic

"The biggest trend over the past year has been remote work as a solution to mitigate the spread of COVID-19," says Matt Malone, Industrial Control system (ICS) Cybersecurity Consultant, Yokogawa Corp. of America (Sugar Land, Tex.; www.yokogawa.com/us). "In our case, it greatly expanded interest in an existing product portfolio of ours, secure remote services. For example, our VPS Remote application (Figure 2) provides access to users of our Centum VP distributed control system from virtually any location. It has provided many of our clients the means to continue working in spite of COVID-19 without sacrificing safety or security. COVID-19 has also accelerated digital transformation in the industry; now, companies are realizing that cybersecurity is a prerequisite to successfully transforming."

"While our secure remote services portfolio had already been on the market leading up to the COVID-19 outbreak, Yokogawa has since launched an entirely-new cybersecurity management solution that bridges IT and OT," says Malone. It is not solely based on technology but brings in numerous, management best practices, he adds.

For instance, companies can invest in general cybersecurity awareness programs for IT, OT and hybrid IT/OT personnel, explains Malone. They can perform security assessments or audits of control systems and control-system networks and increase visibility of control system cyber assets and configurations. They can implement anomaly and intrusion detection tools on control-system networks and invest in cybersecurity education and training for IT, OT and hybrid IT/OT personnel, says Malone.

"Throughout the COVID-19 pandemic, Emerson has worked with customers to provide secure remote services," says Lester. "Leveraging a variety of IIoT technologies and expertise we have enabled services such as non-intrusive health monitoring of valves, equipment performance monitoring and control system health monitoring to meet their operational needs. Secure distributed cloud-based engineering environments have also supported customers with virtual factory acceptance testing (FAT) to ensure projects remain on schedule," Lester says.

"An increased requirement to oper-

ate and maintain plants remotely over the last year has led to new initiatives that ensure remote access is carried out securely," says ABB's Dickinson. "Many of the vulnerabilities exploited by attackers relate to insecure remote access setup, so it's important that an appropriate level of security is embedded in your digital and remote-access solutions," he cautions.

Other product developments

ABB has developed a Secure Reference Architecture (Figure 3) and Cyber Security Risk Assessment Service, both based on IEC 62443, that couples together best practice approaches to securing industrial distributed control systems (DCS). "We work strategically with our customers to identify both their risk exposure and assess the maturity of their system security and security management practices. This enables the identification of appropriate security levels required for each system in order to mitigate cyber security risk to an acceptable level that corresponds to the organization's risk appetite and regulatory compliance requirements," explains Dickinson.

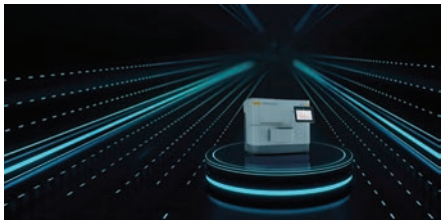
This approach ensures optimal return on investment of cybersecurity improvement programs by ensuring all investments are tied to risk, Dickinson continues. Implementing the recommended security controls to achieve the identified security level will significantly reduce risk, but not eliminate it completely. "To address the residual risk, ABB has developed an event-monitoring service to help our customers effectively monitor their control systems and detect when an attacker has been successful in targeting your systems in order to respond quickly and effectively and thus limit the damage they have on a system," he says.

Meanwhile, Honeywell continues to invest in OT cybersecurity products and services, says Tindill. Some recent new offerings include Honeywell Forge Managed Security Services with Advanced Monitoring & Incident Response. Scheduled to be launched at the end of March, this offering is configured especially for OT environments. "This 24/7-managed security service combines automated analytics with the know-how of certified cybersecurity professionals to help identify, mitigate and manage cybersecurity threats," says Tindill.

Other recent offerings include Honeywell Forge Cybersecurity Suite, the latest release of industry proven software that helps users better manage the operations of OT-centric cybersecurity with improved asset discovery, risk and compliance monitoring and more. Also recently introduced is PCN Hardening Services. "Configured especially for OT networks, this service offers a method of better securing process control systems and network devices by applying elevated security configurations to existing components," says Tindill. ■

Gerald Ondrey

Focus on Analyzers



Malvern Panalytical

This new XRD system is compact, but powerful

In late February, this company launched a new version of its Aeris compact X-ray diffractometer (XRD; photo). Aeris is a small-footprint system that contains capabilities previously only seen in much larger systems. Building on the family of compact Aeris XRD systems that provide high-quality data from polycrystalline materials at competitive speeds, the new Aeris model is designed for use in all environments. Specifically, grazing-incidence XRD enables the examination of thin films and coatings, while transmission measurements provides more accurate data that are not affected by sample-preparation artefacts. The Aeris XRD's straightforward operational interface simplifies XRD measurements for the user. The performance of the Aeris is similar to floor-standing systems, and it does not require any external supplies and infrastructure. The Aeris can also be used in a regulated environment with OmniTrust software. — *Malvern Panalytical B.V., Almelo, the Netherlands*

www.malvernpanalytical.com

Chandler Engineering

Electro-Chemical Devices (ECD)

Determining gas and fluid migration in oil-well cements

The Model 5265 mechanical gel-strength analyzer (MGSA; photo) directly measures the gel strength development of oil-well cement slurries under downhole conditions. The analyzer allows oil service companies and operators to optimize cement slurries and accurately determine the potential for gas and fluid migration between the casing and formation. The Model 5265 MGSA simulates dynamic slurry conditioning during the placement and transition phase of the cement slurry. The unique analyzer design includes a precision motor coupled with a reaction force transducer that allows the instrument to precisely measure phase changes. The system includes a single-cylinder Quizix Q5120 pump to allow for pulse-free pressure operation. Pulse-free pressure prevents test anomalies induced by pump strokes and quick pressure spikes. — *Chandler Engineering, Broken Arrow, Okla.*

www.chandlereng.com

Metso Outotec

Optimize boiler performance with this conductivity analyzer

The high-temperature, high-pressure CSX2 conductivity analyzer (photo) helps ensure boiler performance while minimizing maintenance, repairs and extending operational life in a wide range of critical industrial applications requiring water heating and steam. The analyzer is designed for service up to 392°F (200°C) and 250 psig, or 212°F (100°C) and 400 psig. This insertion-style 0.75-in. MNPT, 316 stainless-steel sensor has PEEK insulators and is available with or without an integral signal conditioner. The device measures conductivity over a wide range from 1.0 µS to 50 mS. A wide range of signal conditioners are available for the CSX2 sensor to optimize the conductivity measurement at specific ranges. The Model LQ800 multi-channel controller or the T80 Transmitter have a user-specified signal conditioner that is mounted inside the CSX2 instrument or optionally in a remote junction box. — *Electro-Chemical Devices (ECD), Anaheim, Calif.*

www.ecdi.com

Metallurgical sampler for production predictability

The Linear Metallurgical Sampler (LMS; photo) enables the measurement of material balances, as well as reporting to investors and other stakeholders in compliance with AMIRA P754 and other sampling standards. The solution enables integration with the company's Courier online analyzers to further improve process control. The LMS incorporates functions to monitor both sampling integrity and sample quality. Its self-diagnostic and self-cleaning systems ensures representative metallurgical samples for improved process audits and production transparency. Maintenance personnel can use self-diagnostics and reporting data to enhance predictive maintenance and spares-management strategies, says the company. Integration of online analyzers will enable different types of sampling data to be combined for production analysis purposes. By combining process history data with different process scenarios, the

process control philosophy can be quickly adapted according to the ore type being processed, for instance. This enables improvement of production predictability and control of metallurgical mass balance. — *Metso Outotec Corp., Helsinki, Finland*
www.mogroup.com

Two analyzers for boiler feedwater, steam and more

The CA76NA monitors sodium, while the CA80SI (photo) analyzes for silica in boiler feedwater, steam, condensate and ion exchangers. Each analyzer can accept up to six sampling inputs. The CA76NA potentiometric analyzer measures the concentration of dissolved sodium ions. An increase in sodium levels in boiler feedwater indicates the presence of unwanted dissolved impurities. This can cause corrosion, leaks, serious damage and expensive repairs. The analyzer monitors the water/steam circuit in power stations, condensate systems for values indicating ruptures, demineralization systems, steam and cation systems, and mixed-bed exchangers. The Liquiline System CA80SI colorimetric analyzer provides precise online analysis of silica to protect plant equipment from deposits to ensure optimum performance of turbines and ion exchangers. Deposits of insoluble SiO_2 on internal boiler walls, heat exchangers and turbine blades have an adverse effect on the efficiency of power plants and increase the risk of unplanned downtime and repairs. For this reason, the silica content in boiler feedwater must be monitored. —*Endress+Hauser, Greenwood, Ind.*
www.us.endress.com

Endress+Hauser

Gas analyzers for qualitative and quantitative analysis

OmniStar (photo) and ThermoStar GSD 350 are compact, portable benchtop analyzers for analyzing gases at atmospheric pressure. They are particularly used for applications in chemical processes, in the semiconductor industry, metallurgy, fermentation, catalysis, freeze-drying and environmental analysis. The gas inlet is fitted with a heated capillary for use at temperatures up to 350°C. This pre-

Pfeiffer Vacuum

Rigaku Europe

Thermo Fisher Scientific

Fritsch

vents vapors from condensing during process gas analysis. Thanks to the two-stage inlet system, an almost segregation-free gas supply is possible. The ThermoStar solution was specially developed for coupling with thermo balances. The inlet system with a quartz capillary and a platinum orifice ensures that even the smallest concentrations can be analyzed. Unlike other analytical methods, such as FTIR or GC-FID, the two new devices allow simultaneous detection of all gases within the mass range. — *Pfeiffer Vacuum GmbH, Asslar, Germany*
www.pfeiffer-vacuum.com

A sixth-generation benchtop XRD diffractometer

This company provides a complete line of X-ray analytical instruments and components, including benchtop X-ray diffraction (XRD) and X-ray fluorescence (XRF) systems, handheld analyzers, X-ray optics and detectors. Among the latest instruments presented at the virtual Analytica Conference (October 19–23, 2020; www.analytica-virtual.com) was the sixth-generation MiniFlex benchtop XRD diffractometer (photo). This multipurpose benchtop XRD system is able to determine crystalline phase identification and phase quantification and perform qualitative and quantitative analysis of polycrystalline materials. Also, the SmartLab high-resolution XRD is an automated, multipurpose system that features guidance software for powder diffraction, thin-film metrology, small-angle X-ray scattering, in-plane scattering and operando measurements. — *Rigaku Europe SE, Neu-Isenburg, Germany*
www.rigaku.com

A powerful GC-MS for research and development needs

Addressing the need for increased flexibility, speed and accuracy in research applications, a new gas-chromatography (GC) high-resolution mass spectrometer (MS) has been introduced with “unrivalled” mass resolving power, sensitivity and wide dynamic range. With the latest system architecture and instrument control software, the system provides simple yet powerful data acquisition capabilities, addressing the most demanding analytical challenges. The Orbitrap Exploris GC 240 MS (photo) has a resolving power of 240,000. By delivering both quantitative and qualitative information from a single injection, the new system enables precise and comprehensive compound identification, allowing researchers to make fast and accurate discoveries. The Orbitrap Exploris GC 240 MS also provides the flexibility to tackle a diverse range of analytical challenges, from identifying unknown contaminants and extractables and leachables, to applied quantification and metabolomics. — *Thermo Fisher Scientific Inc., Austin, Tex.*
www.thermofisher.com

Compact laser particle-size analyzer with extra wide range

The Analysette 22 NeXT laser particle-size analyzer (photo) comes in two versions: the Micro version, which covers the measurements from 0.5 to 1,500 µm, and the Nano version, which has an extra-wide measurement range from 0.01 to 3,800 µm. The NeXT Generation performs the entire measurement process in less than a minute using a flexible-to-program SOP (standard operating procedure). Results are reproducible, and additional parameters, such as temperature and pH during wet dispersion, can be recorded. A powerful, adjustable-speed centrifugal pump distributes the sample uniformly in the entire circuit for stable measurements. An optional ultrasonic box can be added to the sample circuit for samples that tend to agglomerate. — *Fritsch GmbH, Idar-Oberstein, Germany*
www.fritsch.de

A next-generation gas detector for finding leaks

The new Metrex gas-detection instrument (photo, p. 19) is designed for pre-localization, localization and classification of leaks in natural gas distribution networks. The user interface ensures the Metrex is suitable for first-responder technicians who handle suspected gas leaks. Other key applications include bar-hole gas measurement testing, purged gas lines and enclosed-space monitoring. The Metrex is significantly reduced in size compared to its predecessor and is also 50% lighter. Gas measurements are displayed on screen to the user and easy to understand. The IP65-certified ingress rating adds to the robustness of the instrument when operating in adverse weather conditions. ATEX certified (II 2 G Ex db ib IIB T4 Gb), the

new Metrex has been classified to be safely operated in designated hazardous locations. Unlike traditional flame-ionization detectors, the Metrex does not require a technician to carry calibration gas cylinders, because it can perform a user calibration in air. It detects and measures gas ranges from 0 to 10,000 parts per million (ppm). — *QED Environmental Systems, Ltd., Coventry, U.K.*
www.qedenv.com

Transmitter-style GC measures sulfur and natural gas energy

The Rosemount 700XA gas chromatograph (GC; photo) is said to be the industry's first single analyzer for measuring sulfur compounds, as well as the energy content of natural gas. The analyzer offers a cost-effective approach to meet gas-quality and heating-value requirements for pipeline distribution, processing of liquified natural gas (LNG), mixed and high-purity natural gas liquids (NGLs), as well as international LNG commerce. While previous generations of GCs have required the purchase of separate analyzers for sulfur measurement and heating-value analysis, the new Rosemount 700XA gas chromatograph is equipped with a micro-flame photometric detector (FPD), allowing users to reduce initial equipment cost by as much as 50% and footprint requirements by up to 40%, says the manufacturer. The 700XA is a Class 1, Division 1, explosion-proof, ATEX/IECEX safety-rated analyzer, eliminating instrument air requirements for purging or the need for additional protection. — *Emerson Automation Solutions, Shakopee, Minn.*
www.emerson.com

TDL analyzers for chlor-alkali and combustion processes

This company recently enhanced its GPro 500 tunable-diode laser (TDL) gas analyzer series (photo) for better management of corrosion in the chlor-alkali industry and for greater combustion control, as well as increased O_2-measurement accuracy. The GPro 500 TDL H_2O ppm sensor is designed for the measurement of very low moisture levels for corrosion

QED Environmental Systems


Emerson Automation Solutions

Mettler Toledo Process Analytics

Dynatrol

Metrohm

Shimadzu Scientific Instruments

prevention in chlor-alkali plants. The response time of the GPro 500 TDL moisture sensor is below 4 s, which is up to 50 times faster than commonly used phosphorus pentoxide sensors. In situ installation with the GPro 500 can avoid risks of toxic gas leaks and the frequent maintenance typical of extractive systems used with P_2O_5 sensors. The new dual-gas CO ppm/CH_4 % GPro 500 analyzer is designed for combustion applications, which allows measurement of CO in the presence of CH_4. Moreover, in large furnaces with multiple burners, CH_4 measurement provides additional security by detecting a possible malfunctioning burner that has not ignited or ignited only partially. The GPro 500's new MR3 Cell enables O_2 measurement in small pipes. With patented technology, the MR Cell multiplies the path length by a factor of 2 to 3, therefore lowering the detection limit achievable in small spaces. — *Mettler Toledo Process Analytics, Urdorf, Switzerland*
www.mt.com/pro

Inline viscosity measurement of coatings and resins

Designed for high accuracy with fast and continuous readings, the Dynatrol CL-10DV viscometer (photo) operates in a wide range of conditions. It provides excellent results for coatings and resins, as well as supplying outstanding repeatability in Newtonian or shear-thinning liquids. The viscometer utilizes a unique vibratory principle to provide continuous measurement at online process conditions. This eliminates the need for sampling and provides exceptional accuracy. With no moving parts, it is virtually wear-free, ensuring a long operating life. The instrument is CSA NRTL/C approved for Class 1 Group D Div 1. — *Automation Products, Inc. – Dynatrol Div., Houston*
www.dynatrolusa.com

Technique approved for water content in petrochemicals

Since they can be poorly soluble, viscous and often highly contaminated, determining the water content in lubricants, hydraulic oils and other petrochemical samples can challenging. Addressing these challenges, ASTM has revised standard method D6304. The revised standard now includes the Karl Fischer (KF) oven technique. Users can conveniently and accurately determine water content in up to 35 samples automatically by coulometric Karl Fischer titration (photo). Using the KF oven technique, the oil matrix does not come into contact with the titration cell at all. Instead, the samples are introduced in single-use vials, which are put on the rack of an oven sample processor. Heating vial by vial, the water contained in the samples is evaporated. A constant stream of an inert carrier gas is used to bring the water fraction into the titration cell, where it is determined coulometrically. The sample matrix stays in the vials, which are disposed of after the titration. The benefits of this method are considerable, including: no contamination of the KF titration cell; no matrix interferences; less solvents needed; and better reproducibility of results. — *Metrohm AG, Herisau, Switzerland*
www.metrohm.com

Space-saving autoinjector/autosampler for GC

The AOC-30 Series autoinjector/autosampler (photo) is designed to enable gas chromatography (GC) users to produce high-quality results with less downtime. The AOC-30 automatic sample-injection system automates analysis, reduces an operator's workload, and enables continuous analysis with a high degree of accuracy that cannot be achieved by manual operation. The structure of the company's Xtra Life inlet septa results in excellent injection durability and enables continuous analysis that is approximately ten times that of conventional systems — up to 1,000 injections before replacement, says the company. Advanced sample-washing functionality provides continuous analysis without the worry of running out of solvent. Four 4-mL vials can be used in a single tower, and twelve 4 mL-vials can be used with the full tower and sampler system. Users can customize cleaning solvent types and cleaning sequences to optimize the cleaning effect for each analysis. The single-tower system provides automated analysis of up to 30 samples, covering a wide range of analysis needs. Another sample tower or samplers can be added to increase analysis capacity and flexibility. — *Shimadzu Scientific Instruments Inc., Columbia, Md.*
www.ssi.shimadzu.com ■

Gerald Ondrey

New Products

FRS reduces downtime with automated CIP processes

The new No Intervention fines-return system (FRS; photo) allows dairy- and food-powder producers to automate the clean-in-place (CIP) processes of their spray-dryer FRS, leading to reduced downtime, improved working conditions and guaranteed product safety. Explicitly designed for food and dairy spray dryers, the No Intervention FRS uses patented valves to create a smoother and fully automated CIP process, which negates disassembly before and after cleaning. All connections within the FRS remain closed, and once cleaned, can directly be used for production. The valves were developed to comply with hygienic design criteria of the European Hygienic Engineering and Design Group (EHEDG) and have been proven to reduce the risk of CIP liquid leakage and overall contamination. — *GEA Group AG, Düsseldorf, Germany*

www.gea.com

GEA Group

A new frame design extends the life of this pump

The new GD 2500Q Heavy Duty Frame (HDF) quintuplex pump (photo) is designed to extend pump service life through an optimized power-end frame design. The frame upgrade has been developed to increase component thickness and allow for larger, stronger welds to boost structural integrity. The updates include: top and bottom skin plates increased in thickness, offering more structural support for nose-plate loads; main bearing plates with increased thickness that protrude between skin plates with larger, stronger welds, reducing overall frame and weld stress; stronger nose-plate support structure to reduce deflection around welds; and significant size increases in nose-plate welds, which reduces stress in critical joints by more than 20%. — *Gardner Denver High Pressure Solutions (HPS), Houston*

www.gardnerdenverpumps.com

Gardner Denver High Pressure Solutions (HPS)

Next-generation WESP allows for faster installation times

This company recently released a new wet electrostatic precipitator (WESP) that controls air pollution by removing fine particulate matter, acid mists and aerosols from industrial gas streams. In designing the new system, strong focus was placed on the system's high-intensity, offline automatic cleaning features, which reduce maintenance efforts, eliminate carryover of entrained matter during washing and provide better operational performance during cleaning. System components are also now easily accessible for maintenance inspections. Efficient contaminant capture is achieved through increased operating voltage, which requires less collection surface area. Additionally, the gas-distribution system can optimize flow through the system, and various tube shapes and electrodes were tested to improve overall performance. WESPs can remove up to 98% of particulate matter in a single stage, depending on the characteristics of the gas stream. Standardized modules are used in the new design, reducing installation time and streamlining fabrication. Tube bundles come pre-assembled, and electrodes are pre-loaded and pre-aligned. — *Dürr Megtec, De Pere, Wis.*

www.durr-megtec.com

Introducing vacuum-fused wear plates for fans

ColWear Plates (photo) are used in the manufacture and repair of industrial fans to avoid costly downtime and replacement. They protect fans against aggressive industrial environments where fans may encounter a combination of abrasion, particle erosion, pitting/dusting corrosion, surface oxidation and intergranular corrosion at high temperatures. Intense abrasion is a significant issue, because particles in the airstream cause the fan surface to wear away due to friction. This is particularly problematic in the fan blades and scroll housing. ColWear Plates are said to be lighter and more uniform than traditional wear-resistant construction materials. This can make the fan far more energy efficient and more balanced, which is particularly important for the impellers, as it reduces the amount of adjustment required. ColWear Plates can be manufactured with both mild and stainless-steel base materials, as well as higher-grade nickel alloys. — *Wall Colmonoy, Pontardawe, Swansea, Wales*

www.wallcolmonoy.co.uk

Dürr Megtec

Wall Colmonoy

Robust separation seal for a safe compressor shutdown


EagleBurgmann Germany

The CobaSeal (photo) is a robust separation seal with a unique coaxial operating principle. Design studies confirm the CobaSeal maintains its mechanical integrity up to 70 bars and minimizes process gas flow to the bearing cavity when retained properly. The CobaSeal has established an impressive safety and reliability track record. For example, in a particularly challenging application, CobaSeal experts successfully developed a separation seal solution to withstand 200 bars housing pressure. — *EagleBurgmann Germany GmbH & Co. KG, Wolfratshausen, Germany*
www.eagleburgmann.com

A smart temperature transmitter with Bluetooth

The iTEMP TMT142B (photo) is a smart temperature transmitter with Bluetooth connectivity that delivers accurate and reliable measurements, wireless communication via Bluetooth and user-friendly operation — all packaged in a robust single-chamber field housing. The transmitter features a secure, integrated Bluetooth interface that enables users to wirelessly visualize measured values and diagnostic information, as well as perform configuration tasks. The iTEMP TMT142B temperature transmitter is designed for operation in hazardous areas as certified by international approvals (ATEX, CSA C/US, IECEx). — *Endress+Hauser, Inc. Greenwood, Ind.*
www.us.endress.com


Endress+Hauser

Continuously monitoring for corrosion and erosion

This company has introduced a complete corrosion and erosion monitoring portfolio with digital capabilities and full integration with the Plantweb digital ecosystem through the new Rosemount 4390 series of corrosion and erosion wireless transmitters and Plantweb Insight Non-Intrusive Corrosion application. The monitoring portfolio turns existing offline corrosion probes into online tools to monitor for the risk of corrosion or erosion. Combining with non-intrusive Rosemount Wireless Permasense sensors monitoring metal thickness, which is a major factor in determining the health of piping and other fixed equipment, enables users to monitor both the risk of corrosion or erosion, and the impact of that risk on the health of the plant or asset. When instrumented with inline probes, changes in corrosion risk can be detected in minutes, enabling sites to take corrective actions before damage occurs. — *Emerson, Shakopee, Minn.*
www.emerson.com
Mary Page Bailey and Gerald Ondrey


Emerson

A Mixer Makes a Better Sunscreen

Changing from a conventional mixer to an ultra-high-shear mixer led to improved dispersions, increased production capacities, and reduced electricity and labor costs

Department Editor: Gerald Ondrey

As the days get sunnier, people will be looking to sunscreens to protect their skin from the harmful effects of the ultraviolet (UV) rays of sunlight. This is especially true in Australia, where the UV index — a measure of UV intensity (ranging from 0 to 11+) — can be very high. However, a number of ingredients used in commercial sunscreens, are now under scrutiny by the U.S. Food and Drug Administration (FDA; Silver Spring, Md.; www.fda.gov), and may be banned, forcing producers to turn to zinc-based or other alternative blocking agents, which are "generally recognized as safe and effective (GRASE)," according to the FDA.

For Geoff Acton, managing director at Advanced NanoTek Ltd. (ANO; www.advancenanotek.com), the quest for safer alternatives is more than a business — it is a personal advocacy. He is a skin cancer survivor, having undergone more than 30 skin-cancer procedures. "I understand that the sunscreens I used as a child were chemical based suncreens, and may have contributed to the majority of my current issues," he says.

Making ZnO dispersions

ANO was formed in 1997 to commercialize advanced materials technology originally developed by the University of Western Australia. The technology was first scaled up via a joint venture with Samsung Corning Co. in 2000–2004, and has since been a stand-alone operation. The company manufactures zinc-oxide powders (5,000 metric tons per year (m.t./yr) capacity) and ZnO dispersions for zinc-based skincare and sunscreen end products.

For dispersing ZnO into various oils and emulsifying systems, the company had first used a conventional ball mill using various media since 2003. However, these conventional mixers were proving labor intensive and slow. So the company turned to Charles Ross & Son Company (Hauppauge, N.Y.; www.mixers.com) to improve the dispersions.

Acton and his team made several visits to Ross in New York, and Ross performed laboratory tests for ANO. "My world changed meeting Ross," says Acton. "Our chief scientist, Dalia Mizikovsky, identified the X-Series Ultra-High Shear Mixers Ross Mixer [Figure 1] as a potential piece of equipment that could improve the performance of our powder when mixed with ingredients and oils," explains Acton. "When it came time to install the equipment, they [Ross engineers] were able to assist through Skype at very weird hours to handle the time difference between Australia and New York. After initial trials and error, ANO is very excited with the outcomes, he says. "With the X-Series, our product dispersions have improved, and it has enabled ANO's business to increase production capacity by more than double, while reducing the electricity and labor costs. Furthermore, it has enabled us to manufacture bulk intermediate sunscreen, which the current ball-mill system could not."

FIGURE 1. Ross X-Series Ultra-High Shear Mixers enabled ANO to more than double its production capacity while reducing operating and labor costs

Mixer profile

The X-Series Ultra-High Shear Mixer uses a patented design (U.S. Patent No. 5,632,596). The combination of high tip speed and extremely close tolerances between the interlocking channels subjects the product to intense shear in every pass, explains Christine Banaszek, sales manager at Ross. The gap between adjacent surfaces of the rotor and stator is adjustable for fine-tuning shear levels and flowrates. Turning at tip speeds of over 11,000 ft/min, the X-Series rotor consists of concentric rows of intermeshing teeth. Product enters from the center of the stator and moves outward through radial channels in the rotor/stator teeth.

The X-Series Mixer offers a convenient, repeatable method of achieving consistent fine particle size distributions, says Banaszek. "Its robust design tolerates a wide range of viscosities, densities and solids concentrations. It's also easy to clean, sanitize and maintain."

Compared to alternative rotor/stator mixers, fewer passes are required to achieve a good dispersion with the X-Series. As a result, not only is the time required to produce the dispersion reduced, but less energy is required. This translates into lower operating costs and higher productivity, says Banaszek.

Final comments

Despite the impacts of COVID-19 on sales, ANO has recently ordered its fourth mixer. "We now have 540 kg, 216 kg and two laboratory-scale 60-kg mixers," says Acton. "We absolutely recommend to any manufacturer working to mix uncoated zinc-based powders into their products to please consider the Ross mixer." ■

Microbial-Influenced Corrosion

Department Editor: Scott Jenkins

Any corrosion process in which microorganisms initiate, facilitate or accelerate corrosive chemical reactions is termed microbially influenced corrosion (MIC). MIC occurs when the chemical, microbiological and physical conditions allow the active growth of biofilms containing specific types of microbes on the surface of equipment, and the resulting growth fosters the electrochemical reactions that lead to corrosion.

Mechanisms and morphology

Microbial action has been identified as a contributor to rapid corrosion of metals and alloys exposed to a variety of media, including soil, seawater, distilled water, freshwater, crude oil, hydrocarbon fuels, process chemicals and sewage. MIC does not produce corrosion morphology that is distinct from conventional corrosion. MIC often results in pitting, crevice, underdeposit, and galvanic corrosion, as well as dealloying. The presence of water is required, although only a small amount is necessary. Proteins and metabolites secreted from microbes, including sulfide, organic acids and other compounds are often important factors in MIC.

The mechanisms of MIC are not completely understood, because it is generally very difficult to connect the phenomena to a single biochemical reaction or specific microbial species or group. Severe MIC in a natural environment is always caused by microbial communities with many different types of species. Metabolic products of the bacteria alter the interface chemistry, resulting in gradients of dissolved oxygen and pH. These gradients can lead to localized corrosion.

Biofilms

Traditional understanding of MIC involves the formation of biofilms that provide a niche for corrosive microbes to grow and proliferate. Biofilms generally consist mostly of water and extracellular polymeric substances (EPS), which are mostly polysaccharides and proteins that act as structural materials for the biofilm, as well as other microbial metabolites, organic and inorganic molecules. Corrosion-relevant microbes attach to solid surfaces via EPS.

Microorganisms live either in planktonic (free-floating) or sessile (attached) form. For corrosion, planktonic microorganisms are less dangerous. The number and types of microorganisms in the liquid phase of a hydrocarbon, for example, are not necessarily indicative of the potential for MIC, since the sessile microbes have the greatest influence on localized corrosion. Molecular microbiological methods, such as DNA- or enzyme-based test methods, provide important information about biofilm communities.

In aqueous environments, when microbes that prefer to exist in the sessile form adhere to solid surfaces, biofilms form. The metal degradation that occurs with MIC takes place underneath the biofilm. Gradients of microorganisms, oxygen concentrations and pH values exist within biofilms, and these gradients, along with local conditions, form anodic and cathodic sites on metal surfaces. If uncontrolled, localized corrosion occurs, leading to pinholes and leaks .

Bacteria species types

MIC typically takes place in the presence of a community of multiple types of microorganisms. Depending on the environment, these microbes may include sulfate-reducing bacteria (SRB), acid-producing bacteria (APB), metal-oxidizing bacteria, metal-reducing bacteria (MRB) and methanogens. Table 1 provides some information about the types of bacteria that are frequently associated with MIC. ■

TABLE 1. MAIN CLASSES OF BACTERIA INVOLVED WITH MIC

Bacteria type	Description
Sulfate-reducing bacteria (SRB)	SRB are thought to be responsible for the most widespread and economically important MIC. SRB are anaerobic bacteria that obtain energy through anaerobic respiration, by oxidizing organic compounds or molecular hydrogen (H_2), while reducing sulfate (SO_4^{2-}) ion to hydrogen sulfide (H_2S). The presence of H_2S causes serious problems by reacting with metal (mainly iron) ions and producing ferrous sulfide (FeS) on carbon steels. SRB can also corrode steel by the direct uptake of electrons from the metal surface, leading to dissolution of the metal. Examples include bacterial species in the genera *Desulvovibrio* and *Desulfomonas*.
Sulfur-oxidizing bacteria (SOB)	SOB are aerobic bacteria that gain energy by oxidation of the reduced sulfur compounds (such as H_2S) into elemental sulfur, by partial oxidation, or into sulfate. In aqueous environments, the oxidized sulfur species can form sulfuric acid, and thiosulfate ions. Both of these can cause corrosion. Bacteria in the genera *Beggiatoa* and *Paracoccusare* are two classical examples of SOB.
Acid-producing bacteria (APB)	Most APB are aerobic bacteria that use oxygen to consume carbohydrates. Their metabolism can produce organic acids (such as acetic and butyric acids) and other corrosive metabolic byproducts, including inorganic acids (such as sulfuric acid). The metabolic byproducts of APB can also be nutrients for other species (such as fatty acids that are used by SRB). In this way, APB create conditions for increased aggressive activities by SRB.
Iron-oxidizing bacteria (IOB)	IOB, such as those in the genera *Gallionella*, *Sphaerotilus*, *Leptothrix* and *Crenothrix*, oxidize the ferrous iron (Fe^{2+}, a soluble form) to ferric iron (Fe^{3+}, an insoluble iron such as $Fe(OH)_3$). By oxidizing iron, IOB thus produce aggressive ferric chlorides, which cause pits on surfaces of both carbon steel and austenitic stainless steel. A similar process occurs with the oxidation of Mn^{2+} to Mn^{3+}.
Methanogens	Methane-generating species, such as those in the genus *Methanobacteria*, have been associated with steel corrosion in certain conditions. Hydrogenotrophic methanogens can cause metal corrosion directly, through cathodic depolarization, while acetotrphic methanogens can grow syntrophically (in a mutally dependant way) with SRB.

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Suspension Polymerization of Polyvinyl Chloride

By Intratec Solutions

Polyvinyl chloride (PVC) is the third most commonly produced synthetic polymer, after polyethylene and polypropylene. PVC is a white, brittle solid and it comes in two basic forms: rigid (RPVC) and flexible. It can be compounded for a wide range of properties, which allows PVC to be used in a broad range of applications.

This commodity thermoplastic can be manufactured through different polymerization processes, however, most commercial PVC production is based on a suspension polymerization processes. To a lesser extent, PVC is produced at industrial scales via emulsion polymerization and bulk (mass) polymerization.

The process

The suspension process for PVC production comprises three major sections: (1) polymerization; (2) vinyl chloride monomer (VCM) recovery; and (3) drying (Figure 1).

Polymerization. The VCM feed stream, along with hot demineralized water and chemicals (polymerization initiators, dispersing agents and additives) are supplied to a stirred reactor. The reaction occurs substantially in the liquid phase, in VCM droplets dispersed in water, which is used as diluent. After the initiation of VCM polymerization, the heat from the highly exothermic reaction is removed by means of a cooling system, for isothermal temperature control. The molecular weight of the polymer produced is defined by the length of the resulting polymer, which depends on the polymerization temperature. As the polymer is formed, it precipitates out of the reaction medium, floating in the liquid monomer phase. The polymerization is interrupted when the conversion of VCM to PVC reaches about 90%.

VCM recovery. The polymer slurry is fed to a blowdown vessel, operated at a lower pressure than the reactor. Most of the unreacted VCM flashes off. The polymer slurry is pumped to a pre-degassing vessel and a sieve-tray degassing column, where remaining VCM is removed from the polymer suspension. The VCM-rich off-gases are compressed and condensed in liquid-ring compressors and fed to a vessel, in such a way that non-condensed light contaminants are separated from the liquid VCM and released as waste gas. The VCM obtained is recycled to the polymerization reactor.

Drying. The slurry is passed through a solid-bowl decantation centrifuge to obtain a wet PVC cake with residual moisture, which is conveyed to a drying step. The drying stage is a combination of a flash dryer with a cyclone dryer, where the wet PVC cake is dried until its moisture content falls within the 0.2–0.3 wt.% range. The dry PVC powder from the drying stage is then packed for storage.

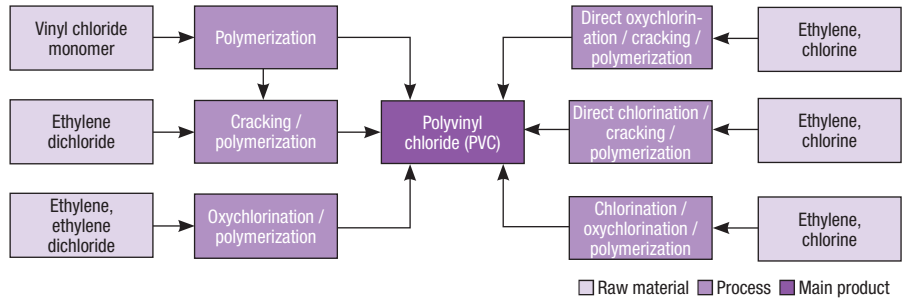

FIGURE 2. PVC production pathways are based on the sources of the monomer

Production pathways

PVC production from VCM can proceed via several different manufacturing routes, each related to different sources of this monomer. In this context, the most typical PVC production routes are based on vinyl chloride produced by reacting ethylene with chlorine (Figure 2).

Economic performance

The total operating cost (raw materials, utilities, fixed costs and depreciation costs) estimated to produce PVC was about $850 per ton of PVC in the second quarter of 2017. The analysis was based on a plant constructed in the U.S. with the capacity to produce 400,000 metric tons per year of PVC.

This column is based on "Polyvinyl Chloride Production from VCM (Suspension Polymerization) – Cost Analysis," a report published by Intratec. It can be found at: www.intratec.us/analysis/polyvinyl-chloride-production-cost. ■

Edited by Scott Jenkins

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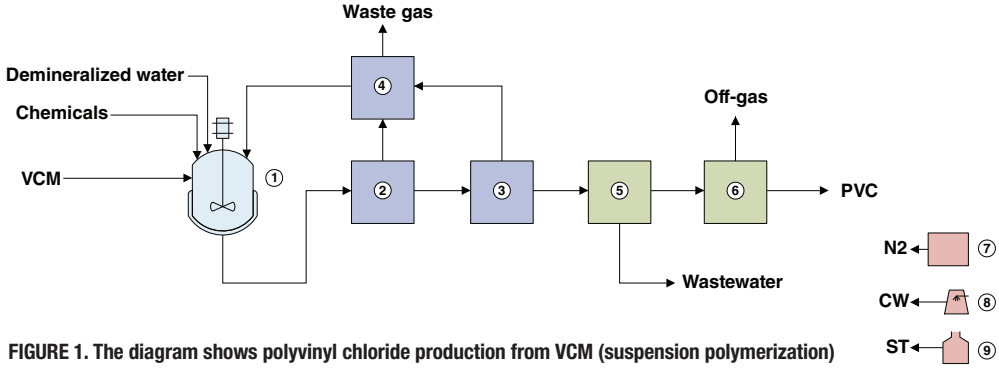

FIGURE 1. The diagram shows polyvinyl chloride production from VCM (suspension polymerization)

Improve Energy Efficiency Using Expanders

Expanders can take advantage of pressure reductions to drive rotating machines. Information on how to assess the potential benefits of installing expanders is provided here

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IN BRIEF

Often in the chemical process industries (CPI), "a considerable amount of energy is wasted in pressure control valves, where high-pressure fluids must undergo a pressure reduction" [*1*]. Depending on various technical and economic factors, it may be feasible to transform this energy into rotational mechanical energy that can be used to drive an electrical generator or another rotating machine. In the case of incompressible fluids (liquids), this is accomplished by using hydraulic power-recovery turbines (HPRTs; explained in Ref. 1). For compressible fluids (gases), expanders are the appropriate machine.

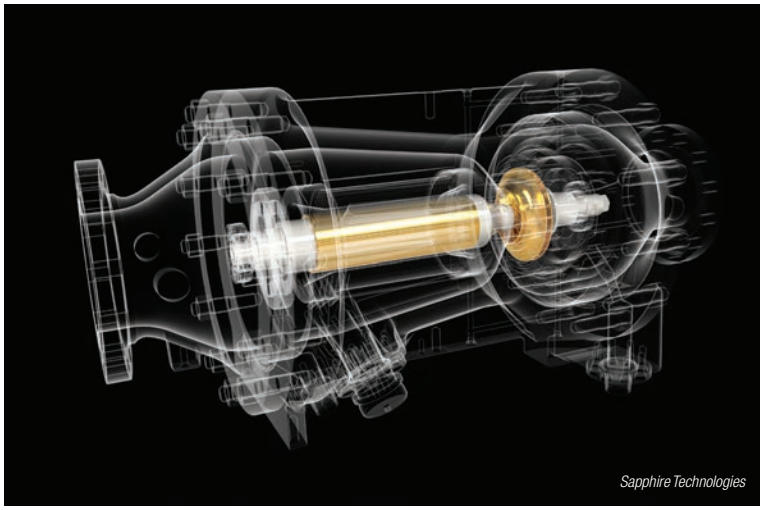

FIGURE 1. This image shows a three-dimensional rendering of an inline turboexpander

Expanders are a mature technology with a host of successful applications, such as fluid catalytic cracking (FCC), refrigeration, natural-gas city gate-valve stations, air separation or off-gas venting, to name a few. Basically, any gas stream subject to a pressure reduction can be used to drive an expander, yet "the energy output is proportional to pressure ratio, temperature and flowrate of the stream" [*2*], and the technical and economic feasibility of implementing expanders in a process depends on these and other factors, such as the local price of energy and the availability of suitable machines from manufacturers.

While turboexpanders (which function in a manner similar to that of turbines) are the best-known type of expander (Figure 1), there are other types suitable for different process conditions. This article describes the main types of expanders and their components, and summarizes how operations managers, consultants or energy auditors in various sectors of the CPI can assess the potential economic and environmental benefits of an expander installation.

Expander types

There are many different types of expanders, varying widely in geometry and capability. The main types are shown in Figure 2, with a brief description of each given below. Further details and a chart comparing the operating regimes of each of these types as a function of specific diameter and specific speed can be found in Ref. 3.

Piston turboexpander. Piston and rotary-piston turboexpanders operate like backward combustion engines, taking high-pressure gas and converting its stored

energy into rotational energy through a crank shaft.

Drag turboexpander. Drag turboexpanders consist of a concentric flow cavity with scoop-shaped fins fixed to the periphery of the rotating element. These are designed much like a water wheel, but the concentric cavity gradually increases in cross section from inlet to outlet, allowing for expansion of the gas.

Radial turboexpander. Radial turboexpanders are designed with axial-flow inlets and radial-flow outlets, such that the gas is expanded radially through the turbine wheel. Similarly, axial-flow turbines expand gas through the turbine wheel, but the direction of flow remains parallel with the axis of rotation.

The main focus in this article is on radial and axial turboexpanders, discussing their various subtypes, components and economic benefits.

Turboexpanders recover energy from high-pressure gas streams and convert the energy to drive a load. Generally, the load is either a shaft-coupled compressor or an electric generator. Compressor-loaded turboexpanders compress a fluid in other parts of the process stream requiring a compressed fluid, and thus increase the overall plant efficiency by utilizing otherwise wasted energy. Generator-loaded turboexpanders convert the energy into electricity, which can be used in other plant processes or returned to the local electrical grid for sale.

Turboexpander generators can be configured with a direct-drive shaft from the turbine wheel to the electric generator or through a gearbox, which effectively reduces the input speed from the turbine wheel to the generator through a gear ratio. Direct-drive turboexpanders are superior in terms of efficiency, footprint and maintenance costs. Gearbox turboexpanders are much heavier and require a larger physical footprint, auxiliary oil lubrication equipment and regular maintenance.

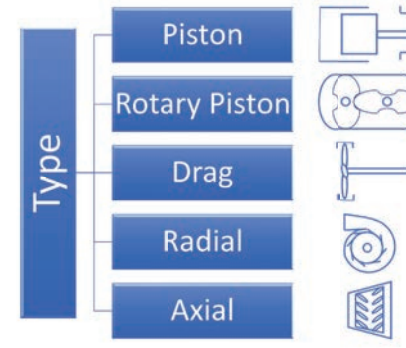

FIGURE 2. Different types of expanders vary widely in their geometries and their capabilities

Flow-through turboexpanders can be designed with radial or axial turbines. Radial flow-through expanders contain an axial inlet and a radial outlet such that the gas flow exits the turbine radially from the axis of rotation. Axial flow turbines allow the gas to flow axially along the axis of rotation. Axial turbines extract energy from the gas flow via inlet guide vanes to the expander wheel, while the cross-sectional area of the expansion chamber gradually increases to maintain constant velocity.

Components

A turboexpander generator has three primary components: turbine wheel, specialized bearings and generator.

Turbine wheels. The turbine wheels are typically designed specifically for the application, in order to optimize aerodynamic efficiency. Application variables

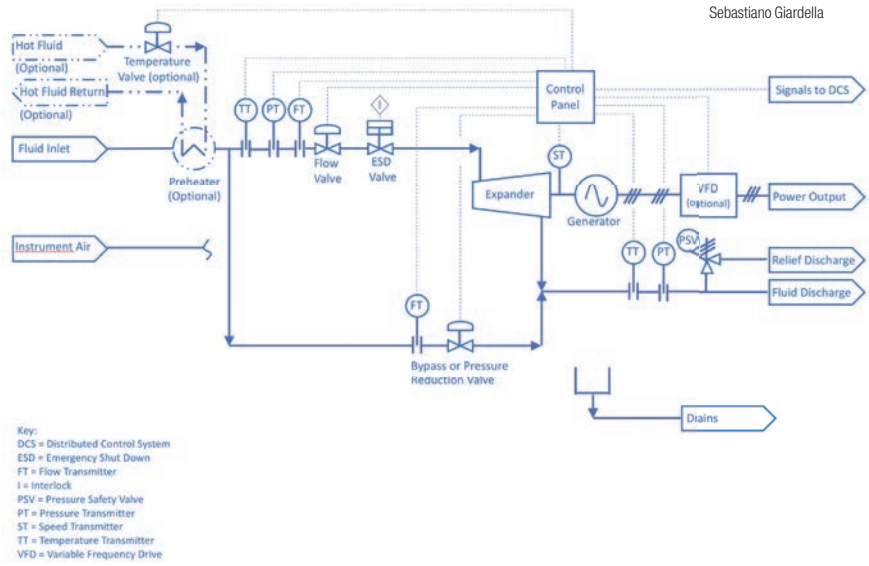

FIGURE 3. The diagram shows an example of an overall process arrangement for an expander generator

affecting turbine wheel design include inlet/outlet pressure, inlet/outlet temperature, amount of volumetric flow and fluid characteristics. Turboexpanders with several turbine wheels are required when the pressure ratio is too large to reduce via a single stage. Both radial and axial turbine wheels can be designed with multiple stages, but the axial turbine wheel has a much shorter axial length and thus is more compact. A radial multi-stage turbine requires the gas to flow from axial to radial, then back to axial again, and thus produces higher friction losses than the axial turbine.

Bearings. Bearing design is critical for efficient turboexpander performance. Bearing types associated with turboexpander designs vary widely and can include oil lubrication, fluid film, conventional ball and magnetic. Each has its own advantages and disadvantages, as summarized in Table 1.

Many turboexpander manufacturers are transitioning to magnetic bearings as the "bearing of choice," due to their distinct advantages. Magnetic bearings provide frictionless operation for the dynamic components of the turboexpander, dramatically reducing operating and maintenances costs over the life of the machine. They are also designed to adapt to a wide range of axial and radial loads and surge conditions. Their higher upfront costs are offset by much lower lifecycle costs.

Generator. The generator takes the rotational energy from the turbine and converts the energy into useable electricity through an electromagnetic generator, which can be either an induction or permanent magnet (PM) generator. Induction generators are rated for lower speed, and thus require gearboxes for high-speed turbine applications, but are capable of being designed to match the frequency of the grid, thereby eliminating the need for a variable frequency drive (VFD) to transfer the generated electricity. PM generators, on the other hand, can be directly shaft-coupled to the turbine, and can deliver electricity to the grid via a VFD. The generator can be designed to output the maximum amount of electricity according to the available shaft power of the system.

Seals. Sealing is also a critical component in designing a turboexpander system. To maintain high efficiency and meet environmental standards, systems must be sealed to prevent potential process gas leaks. Turboexpanders can be designed with dynamic or static seals. Dynamic seals, such as labyrinth seals and dry gas seals, provide sealing around the rotating shaft, usually between the turbine wheel and the rest of the machine where the bearings and generator are located. Dynamic seals wear over time and require regular maintenance and inspection to ensure they are working properly. Static seals may be used when all components of the turboexpander are contained inside one housing, protecting any lead wires exiting the housing, including leads for generators, magnetic bearing actuators or sensors. These hermetic seals provide permanent protection against gas leaks and do not require any maintenance or servicing.

Expander process arrangement

From a process point of view, the basic requirements for an expander installation are a high-pressure compressible (non-condensable) gas being delivered to a lower-pressure system at a sufficient flowrate, a pressure differential and a use factor to maintain the equipment's working parameters within safe and efficient levels.

From a pressure-reduction function, expanders can be used to replace a Joule-Thomson (J-T) valve, also known as a throttling valve. Given that the J-T valve follows an isenthalpic path,

whereas the expander follows a nearly isentropic path, the latter reduces the gas enthalpy, with the enthalpy difference being transformed to shaft power, achieving a lower outlet temperature than the J-T valve. This is useful in cryogenic processes aiming to reduce the temperature of the gas.

In cases where there is a lower limit to the outlet-gas temperature (for example, in pressure letdown stations, where the temperature of the gas must remain above freezing, hydrate-formation or minimum design-material temperature), at least one heater is added to control the gas temperature. When a preheater is located ahead of the expander inlet, part of the energy supplied to the gas is also recovered in the expander, thus increasing its power output. In some configurations where outlet temperature control is essential, a second post-heater can be installed after the expander to ensure a faster control.

A simplified diagram of the overall process arrangement for an expander generator with a preheater used to replace a J-T valve is shown in Figure 3.

In other process configurations, the energy recovered in the expander can be directly transferred to a compressor. These machines, sometimes referred to as "companders," typically have the expander and compression stages linked via one or multiple shafts, which may also include a gearbox to adjust for speed differences between both stages. It may also include an additional motor to supply more power to the compression stage.

Described below are some of the most important components that ensure the proper operation and stability of the system.

Bypass or pressure-reduction valve. A bypass valve allows service continu-

TABLE 1. BEARING TYPES FOR TURBOEXPANDERS

Category	Ball	Fluid Film	Air	Magnetic
Adaptive to variable loads				✔
High speed applications			✔	✔
High stiffness	✔		✔	✔
Low cost	✔			
Low parasitic load			✔	✔
Maintenance Free Operation			✔	✔
Minimal wear		✔	✔	✔
Moisture tolerance	✔	✔		
No auxiliary pumps/compressors	✔			✔
No rotor contact/friction		✔	✔	✔
Particulate tolerance				✔
Used in process fluid stream	✔			✔

ation when the turboexpander is taken out of service (for example, to perform maintenance or during an emergency), whereas a pressure-reduction valve is used in continuous operation to deliver excess gas, when the total flow exceeds the expander design capacity.

Emergency shutdown (ESD) valve. An ESD valve is used to stop gas flowing into the expander during a contingency to prevent mechanical damage.

Instruments and controls. Important variables to monitor include inlet and discharge pressures, flowrate, rotational speed and power output.

Overspeed trip. This device shuts off the flow to the turbine, which causes the turbine rotor to decelerate, protecting the equipment from an excessive speed derived from unexpected process conditions that could damage the equipment.

Pressure safety valve (PSV). A PSV is usually installed downstream of the turboexpander to protect the low-pressure line and the equipment. The PSV must be sized for the worst contingency, with typical cases including bypass valve failure open. In cases where the expander is added to an existing pressure letdown station, the process design team should determine if the existing PSV already provides adequate protection.

Preheater. A preheater compensates for the temperature decrease caused by passing gas through the turbine, making it necessary to preheat the gas. Its main role is to increase the temperature of the upstream flow to maintain the temperature of the gas at the expander discharge above minimum values. The temperature increase has the added benefit of increasing power output while also avoiding corrosion, condensates or hydrates that can have a detrimental effect on the nozzle of the equipment. In systems containing heat exchangers (such as the one shown in Figure 3), gas temperature is typically controlled by regulating the flow of heating fluid to the preheater. In some designs, a fired or electric heater may be used instead of a heat exchanger. In existing J-T valve stations, a preheater may already exist, and the addition of an expander may not require further preheaters to be installed, but rather an increase in heating-fluid flowrate.

Lube oil and seal gas systems. As described above, expanders may use different seal designs, which may require lube oil and seal gas. Where applicable, the lube oil must be maintained at high quality and purity as it encounters process gas, and the viscosity levels of the oil must be maintained within the required operation ranges of the oil bearings. A seal gas system generally accompanies a lube oil installation to prevent the oil from the bearing housing from entering the expander housing. In the particular case of companders for use in the hydrocarbons industry, it is common to design lube oil and seal gas systems to API 617 [*5*] Part 4 specifications.

Variable frequency drive (VFD). When the generator is asynchronous, a VFD is typically included to adjust the alternating current (a.c.) signal to match the frequency of the grid. Typically, designs that rely on VFDs have higher overall efficiencies than those with gearboxes or other mechanical components. Systems based on VFDs also can accommodate a wider range of process variations that may result in varying expander shaft speeds.

Gearbox. In some expander designs, a gearbox is used to reduce the rotational speed of the expander to match the generator's nominal rotational speed. The use of a gearbox comes at the expense of a reduction in overall efficiency, and hence output electrical power.

Expander process design

When preparing a request for quotation (RFQ) for an expander, process engineers must first define the service conditions, including the following information:

- Operating conditions (inlet and outlet pressure, differential pressure, flow-rate, inlet temperature)
- Fluid properties (including gas composition, molecular weight, viscosity, specific heats ratio, dewpoint, presence of corrosive or condensable components)
- Design conditions (inlet and outlet design pressure, design temperature and rating)
- Site and utility data (location, elevation, atmospheric conditions, utility conditions, such as electricity, cooling fluid, instrument air or steam or heating fluid). Where multiple operating cases are foreseen, process engineers should clearly identify these cases, as well as extremes of process parameters (for example, minimum and maximum inlet pressure) and provide process data for each. They may also provide a sketch of the proposed facilities, such as a process flow diagram (PFD) or piping and instrumentation diagram (P&ID)

Mechanical engineers typically complete the expander generator data

sheets and specifications with the inputs from other engineering disciplines. These inputs may include the following:

- Design code requirements
- Electrical area classification
- Electrical and instrumentation requirements
- Civil/structural design with seismic and wind design data

The specifications should also include a list of documents and drawings to be supplied by the manufacturer as part of the bidding process and as part of the scope of supply, along with test procedures, as applicable, according to project requirements.

Technical information to be provided by the manufacturer as part of the bidding process should typically include the following items:

- Predicted performance (hydraulic power, power output at generator terminals, outlet gas conditions) at each specified case
- Performance curves, utility requirements and auxiliary electrical consumption
- Preliminary drawings
- Technical description
- Scope of supply
- A list of spare parts
- A list of engineering deliverables to be supplied and warranties

If any aspects of the proposal differ from the original specifications, then the manufacturer should also provide a list of deviations along with the reasons for the deviations.

The project design team, upon receipt of the proposals, must then check compliance with the RFQ, and determine whether any deviations are technically justifiable.

Other technical considerations that should be taken into account when evaluating proposals include the following:

- Space and utility requirements
- Warranties offered
- Lead times
- Operational limits
- Technical support and remote monitoring capabilities
- Past performance
- Maintenance requirements
- Other criteria as valued by the project team

Finally, an economic analysis should be performed. Since different options may present different initial costs, it is recommended to perform a cash-flow or lifecycle-cost analysis to compare long-term project economic performance and return on investment. For instance, a higher initial investment can be compensated in the long run by better performance or by reduced maintenance requirements. For guidance on this type of analysis, see Ref. 4.

Calculating power potential

All turboexpander generator applications require an initial calculation of total power potential to determine the total amount of available energy that can possibly be recovered in a specific application. For turboexpander generators, the power potential is calculated as an isentropic (constant entropy) process. This is an ideal thermodynamic case considering a frictionless, reversible adiabatic process, but it is the proper process for estimating realistic power potential.

Power potential is dependent on the following input parameters:

- Gas composition
- Inlet pressure, kPa-gage
- Exit pressure, kPa-gage
- Inlet temperature, °C
- Normalized volumetric flowrate (0°C and 1 atm), Nm^3/h

The isentropic power potential (IPP) is calculated by taking the difference between the specific enthalpy between the inlet and exit of the turboexpander, and multiplying the result by the mass flowrate. This power potential will be expressed as an isentropic value (Equation (1)):

$$IPP = (h_{inlet} - h_{(i,e)}) \times \dot{m} \times \eta \quad \textbf{(1)}$$

Where, $h_{(i,e)}$ represents the specific enthalpy, considering isentropic exit temperature, and $\dot{m}$ is mass flowrate.

Although the isentropic power potential is useful in estimating power potential, all real-world systems contain friction, heat and other auxiliary energy losses. Thus, a realistic power potential calculation should consider the following

additional inputs:

- Desired exit temperature, °C
- Total turboexpander system efficiency, %

In most turboexpander applications, the temperature is limited to a minimum value to prevent unwanted issues, such as freezing pipelines, as mentioned previously. In the case of natural gas flow, hydrates are almost always present, which means the pipes downstream from a turboexpander or J-T valve will freeze internally and externally if the exit temperature drops below 0°C. Freezing causes restrictions in flow and eventually downtime to defrost. Thus, a "desired" exit temperature is used to calculate a more realistic power potential scenario. However, for gases such as hydrogen, temperature limitation is much lower because hydrogen does not change phase from gas to liquid until it reaches cryogenic temperatures (–253°C). Specific enthalpy is calculated using this desired exit temperature.

Turboexpander system efficiency must also be considered. System efficiency can vary widely depending on the technology being used. For example, a turboexpander that utilizes a step-down gearbox to transmit rotational energy from the turbine to generator will experience far greater friction losses than a system that uses a direct drive from the turbine to the generator. Total turboexpander system efficiency is expressed as a percentage and is considered when estimating actual turboexpander power potential. The realistic power potential (PP) calculation is as follows:

$$PP = (h_{inlet} - h_{exit}) \times \dot{m} \times \eta \quad \textbf{(2)}$$

Where:

$h_{(i,e)}$ = specific enthalpy, considering isentropic exit temperature

$\dot{m}$ = mass flowrate

η = turboexpander system efficiency

Example 1: Natural gas PP calc.

Let's consider a natural-gas pressure let-down application. Company ABC runs and maintains a pressure let-down station that delivers gas from a main

pipeline and distributes the gas to a local municipality. At this station, inlet gas pressure is 40 bar, while the exit pressure is 8 bar. The inlet temperature of the gas with pre-heating is 35°C, and the gas is pre-heated to prevent freezing pipelines. Thus, the exit temperature of the gas should be controlled such that it will not drop below 0°C. In this example, we will use 5°C as a minimum exit temperature to add a factor of safety. The normalized volumetric flowrate of the gas is 50,000 Nm^3/h. To calculate power potential, we will assume all the gas flows through the turboexpander and calculate a maximum power output. The following calculation is made to estimate the total output power potential:

Natural gas mixture:

- Methane: 95.1%
- Nitrogen: 0.1%
- CO_2: 2.5%
- Ethane: 3.3%
- Propane: 0.6%
- Isobutane: 0.1%
- Butane: 0.1%
- Inlet pressure: 40 bar (4,000 kPa-gage)
- Exit pressure: 8 bar (800 kPa-gage)
- Inlet temperature: 35 °C
- Exit temperature: 5 °C
- Normalized volumetric flowrate (0°C and 1 atm): 50,000 Nm^3/h
- Turboexpander system efficiency: 93%

The power potential available in this case is 342 kW at 5°C. The isentropic power potential is 1,754 kW, which indicates that further optimization may be considered. Further optimization may include increasing the temperature of the inlet gas stream by providing additional pre-heating. Doing so will increase the amount of recoverable energy from the stream, but it only makes sense if the spark spread is significant enough for a beneficial economic case. The spark spread is the difference between the wholesale price of electricity and its cost of production using natural gas.

Example 2: H_2 PP calculation

Another applicable gas for turboexpanders is H_2. With the global energy industry looking more at hydrogen as a long-term clean-energy solution, development of a H_2 infrastructure is rapidly growing. As with natural gas, H_2 pressure is transmitted at high pressures and let down at specific locations for production, storage and consumption. The distinct pressure let-down cases for H_2 are the cryogenic liquefaction process from liquid transportation to gas storage, from gas storage to gas distribution and from gas distribution and local transportation to consumption. During the hydrogen liquefaction process, H_2 is compressed and cooled to its inversion point, where the temperature is further reduced while the gas expands to finally reach its liquefaction temperature of –253°C. This liquefaction process allows efficient, high density transportation of H_2 throughout its infrastructure.

Consider a H_2 fueling station example where gaseous H_2 is transferred from a fuel tanker to a storage tank. In this case, hydrogen's storage pressure in the tanker is 275 bar with a temperature of 60°C. The storage tank required pressure is 18 bar. The gaseous H_2 is dispensed into the filling station storage tank at a rate of 5,000 Nm^3/h. The trailer is emptied in 3.5 hours, with a turboexpander operating during the first half of this timeframe, while a compressor operates during the second half.

- Process fluid: gaseous H_2
- Inlet pressure: 275 bar (27,500 kPa-gage)
- Exit pressure: 18 bar (1,800 kPa-gage)
- Inlet temperature: 60°C
- Exit temperature: not critical
- Normalized volumetric flowrate (0°C and 1 atm): 5,000 Nm^3/h
- Turboexpander system efficiency 93%

The power potential available from Equation (2) is 318 kW and would be dispensed into the storage tank at a temperature of –124°C. In this case, the power produced would be returned to the electrical grid or to provide supply for the immediate facility. During the second half of the emptying process, the compressor will be activated to fully dispense the hydrogen from the tanker. This

case is an example of a net-zero process. Using a turboexpander, we can recover energy losses and offset electrical requirements and CO_2 emissions.

Example 3: Economic case

Recovery of lost energy through turboexpanders is beneficial to overall plant efficiency, and it offsets electrical requirements and reduces CO_2 emissions, but decisions on whether or not to use a turboexpander must include a financial component of the equation as well. Installation of a turboexpander is a capital expenditure (CAPEX), so the payback period should be carefully evaluated to ensure the CAPEX makes financial sense. There may also be potential government incentives for offset of CO_2 emissions and sale of electricity to the grid. These variables are the building blocks for a valuable economic case for a turboexpander. To build a simple and straightforward economic case, the following inputs and outputs should be considered:

Inputs:

- Technical specifications (pressures, temperatures, flowrate and so on)
- System purchase price
- System installation price
- Wholesale price of electricity
- Price of natural gas (for pre-heating in natural gas PLD)
- Plant capacity factor (what percentage of a day does the plant run?)

Outputs:

- Payback period
- Electricity produced
- CO_2 emissions offset
- Annual revenue

Using the natural gas example from company ABC (Example 1), we can build an economic case for the purchase and installation of a turboexpander. First, we look for market availability of a turboexpander with the appropriate power production for our application. In this example, we will use a 280-kW turboexpander. The price for this system is $300,000 and the installation costs are $50,000. The wholesale price of electricity for the region where this plant is located is $0.16/kWh, while the price of natural gas for pre-heating is $0.06/kWh, bringing the spark spread to $0.10/kWh. The plant operates about 20 hours per day, which we will round to 85% of the day, with an average flowrate of 50,000 Nm^3/h.

We will need to optimize the flow through the turboexpander to achieve maximum power production. Since there is 342 kW of available power, we will divert 41,000 Nm^3/h of flow through the turbo-expander, while the remaining 9,000 Nm^3/h flows through the pressure-reduction valve.

Based on the power production

and wholesale price of electricity, we will generate a total of $334,000 per year of electrical revenue. The cost for pre-heating the gas from 20°C to 35°C is $175,000 per year. Subtracting the two, we get a net revenue after pre-heating of $159,000 per year. To calculate the payback period, we divide the CAPEX ($350,000) by the net revenue, yielding a payback period of 2.2 years. This amounts to quite an expeditious payback period for a capital expenditure.

The annual electricity produced can be calculated by multiplying the kilowatt-electric produced by the number of hours per day times the number of days per year. We get about 2.0 Gigawatt-hours of power production per year, which is equivalent to 1,000 tons of CO_2 emissions offset per year [5].

Concluding remarks

Turboexpander generators are a mature technology and an ideal candidate for gaseous pressure let-down (PLD) applications. Turboexpander generator design has become more efficient and cost-effective through the integration of magnetic bearings, permanent-magnet motors and variable-speed drives. As global energy demand continues to increase, it is imperative for plant processes to be optimally efficient. Recovering lost energy from PLDs can reduce CO_2 emissions, increase overall plant efficiency, offset electrical costs and generate additional revenues. ■

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Controlling Air Pollution with Ceramic Catalytic Filters

Catalyst-impregnated ceramic filter elements can achieve simultaneous removal of multiple air-pollutant species in a modular, space-saving layout

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IN BRIEF

The three most common pollutants found in the air we breathe are particulate matter (PM), nitrogen oxides (NOx) and sulfur oxides (SOx). These three major sources of pollution can trigger respiratory difficulties and asthma, as well as cause environmental harm in the forms of acid rain, visibility impairments and water-quality impacts. The U.S. Environmental Protection Agency (EPA; Washington, D.C.; www.epa.gov) regulates all three pollutants, which may be emitted in fluegas from coal-fired power plants, fertilizer plants, glass manufacturing plants, cement plants, petroleum refineries and other industrial facilities. The EPA manages a comprehensive enforcement and compliance database of thousands of industrial plants in the U.S. via the Enforcement and Compliance History Online (ECHO) system (echo.epa.gov).

Currently, industrial pollution-control equipment installations are dominated by baghouse fabric filters and electrostatic precipitators (ESPs). Simultaneous removal of the three major pollutants from fluegas can also be achieved with catalyst-impregnated ceramic filter elements within one housing-boxed system (Figure 1). Such catalyst ceramic filtration (CCF) installations can achieve simultaneous pollutant removal with lower capital expenditure and plot-space requirements than traditional baghouse or ESP configurations. Figure 2 summarizes the removal efficiencies of a CCF unit for various pollutants. CCF systems have seen successful installations in many industrial applications, including the following:

- Hazardous waste incineration
- Industrial waste incineration
- Glass industry furnaces (float glass, tableware and container)
- Biomass energy plants
- Synthesis gas (syngas) processing
- Regenerative thermal oxidizer exhaust
- Ceramic kiln exhaust
- Catalyst manufacturing
- Munitions incineration

FIGURE 1. Multiple pollutants in fluegas can be effectively treated with ceramic catalytic filter (CCF) elements. This system shows five installed filter boxes

Tackling air pollution

To understand the process specifics for CCF systems, it is first important to outline the traditional treatment technologies for the major air pollutants: NOx, SOx and PM. These methods are described in the following sections.

NOx treatment. Oxides of nitrogen (NOx) include nitrogen dioxide and nitric oxide. Common technologies used to remove NOx are selective catalytic reduction (SCR), which reacts NOx with ammonia at around 700°F with the aid of a catalyst, and selective non-catalytic reduction (SNCR), which reacts with ammonia at even higher temperatures to reduce NOx emissions. Catalytic reduction of NOx is typically performed at a temperature range between 600 and 700°F. The NOx-reduction operation is performed by injecting an ammonia-based reagent.

In applications with high-temperature furnace off-gas (around 1,150°F), water spray injection, fresh air dilution or heat exchangers can

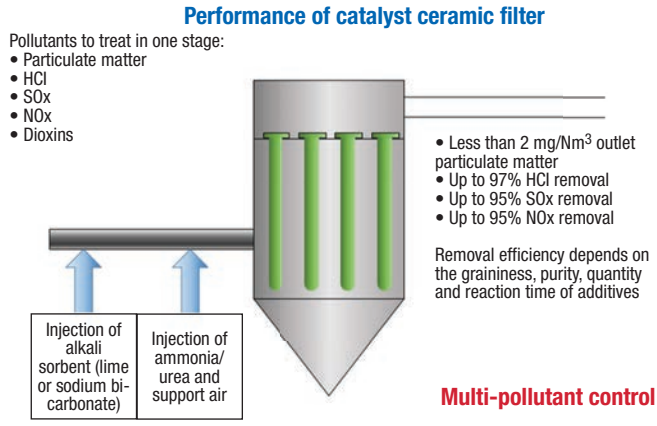


FIGURE 2. A CCF system can simultaneously remove multiple pollutants, including SOx, NOx, particulate matter and dioxins

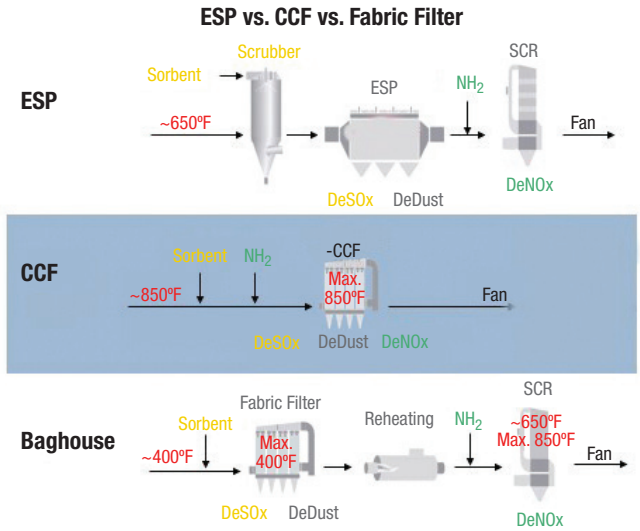


FIGURE 3. CCF installations have a more compact equipment layout than other air-pollution-control technologies, such as fabric baghouse filters or electrostatic precipitators (ESP)

be used to cool and control the gas velocity and temperature distribution in order to reach the optimum reaction conditions.

In order to avoid the risk of undesired formation of ammonium sulfate (AS) or ammonium bisulfate (ABS) at lower temperatures, the inlet temperature must be controlled to remain above 662°F. The ammonia-based gas thus created then reacts with the NOx over a catalyst. Catalysts typically consist of TiO_2, V_2O_5 or WO_3. The main reactions occurring in catalytic NOx treatment are as follows:

1. $NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3\ H_2O$ (fast)
2. $4NO + 4NH_3 + O2 \rightarrow 4\ N_2 + 6\ H_2O$ (slow)
3. $2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$ (slow)

SOx treatment. Sulfur oxides (SOx), mainly SO_2, are of concern due their potential to create sulfuric acids. For SOx removal, the commonly used equipment are wet fluegas desulfurization (WFGD), the circulating dry scrubber (CDS) and the semi-dry scrubber (SDA). In FGD, lime reacts in operating temperature ranges be-

FIGURE 4. Tubular filter elements imbue CCF installations with high internal surface area

tween 350 and 1,200°F with SO_2 in order to form salt and water through the following reaction, where calcium hydroxide (hydrated lime) and sodium-based sorbents are used, such as sodium bicarbonate or Trona (trisodium hydrogendicarbonate dihydrate):

$$Ca(OH)_2 + SO_2 + \tfrac{1}{2}O_2 \rightarrow CaSO_4 + H_2O$$

Processed PM and neutralization residues are then transported through a pneumatic conveying system to an intermediate storage silo or to the batch house for reuse.

Acid-gas neutralization is performed via the injection of high-specific-area hydrated lime in the duct upstream of the catalyst-embedded ceramic filters with a dry sorbent injection (DSI) technology. The contact between acid gases and hydrated lime particles is increased because the outgoing gases must pass through the filtration cake layer containing the hydrated lime deposited on the outer surface of the CCF element.

PM treatment. PM comprises a mixture of solid particles, liquid droplets, dust, dirt, soot and smoke (ranging from 2.5 to 10 microns [µm] in size). The mixture can contain varied components, such as bases, acids, other chemicals, liquids, solids, metal dust and gas particles, which are commonly removed using a baghouse fabric filter or a wet or dry ESP. The EPA regulates PM content through established air-quality standards based on particle size, including PM2.5 regulations (related to fine particles less than 2.5 µm in diameter) and PM10 regulations (related to particles less than 10 µm in diameter).

Multi-pollutant control

As previously mentioned, there are several common methods (including SCR, SDA and baghouses) found in industry to remove NOx, SOx and PM. Depending on the application, there are various types of equipment used in such air-pollution-abatement technologies. These are summarized in Table 1. Technology selection will depend on application needs and best available technologies (BAT).

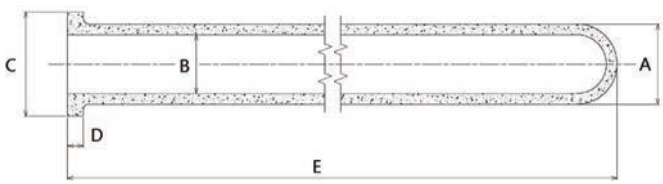
Cost-comparison studies have been completed to compare one system combination of equipment with other combinations for various industrial applications. An in-depth study undertaken by the Economic Commission for Europe [*1*] provides comprehensive information on selection of air-pollution-control methods.

A primary benefit of utilizing CCF configurations is to reduce the amount of equipment being used and hence reduce the onsite footprint, as shown in Figure 3. Other benefits of CCF units include their resistance to high temperatures and corrosion, long lifecycle (5- to 10-year operating life of the catalyst filter elements), high heat-recovery efficiency and relatively low operating costs.

Fabric filters (also called baghouses) and ceramic filters can capture over 99.9% of particulate matter, including PM2.5. These become multi-pollutant systems when combined with sorbent injection (as shown in Figure 3) to remove additional pollutants, such as mercury, SOx and other acid gases. NOx can be removed via SCR catalysts incorporated into the filter elements and upstream injection of ammonia or, if the temperature is sufficiently high, urea.

Ceramic filters are also called candle filters because of their solid tube shape. Low-density ceramic filters can be provided with or without an embedded catalyst.

The use of CCF box systems allows for multi-pollutant control in



Code	Description	Dimension
A	Element outer diameter	150 mm
B	Element inner diameter	110 mm
C	Flange outer diameter	195 mm
D	Flange height/thickness	30 mm
E	Element length	3,000 mm

FIGURE 5. This diagram shows typical dimensions for CCF structures

FIGURE 6. Filter elements are self-supported with an integral flange

TABLE 1. AIR-POLLUTION ABATEMENT UNIT OPERATIONS

Technology	Equipment Type
Gravitational separation	Cyclone
Dust scrubber	wet FGD, CDS, SDA, spray tower, Venturi
Filters	Fabric, ceramic, electrostatic (dry or wet)
Condensation	Condenser
Adsorption	Zeolites, lime injection
Absorption	Gas scrubber
Biological cleaning	Bio-filtration, moving-bed trickling filter
Thermal oxidation	Incinerator, recuperative, regenerative
Chemical reduction	SCR, SNCR
Other	Membrane filtration

one step. Beyond their smaller footprint for multi-pollutant removal of SOx, NOx and PM, CCF systems have also been shown to remove dioxins and heavy metals. Furthermore, CCF installations, due to their smaller footprint, typically have a lower pressure drop across the system, and require less maintenance and consume fewer utilities than other pollution-control technologies. CCF systems can run at high exhaust-gas temperatures (greater than 350ºF) and typically operate far away from acid and water dewpoint temperatures. Their modular nature means that one filter box can be maintained individually without interrupting operation. Filter cake removal is achieved by automatic online pulse-jet cleaning.

Ceramic filter fabrication

Candle-shaped ceramic filters are rigid tubes, with 80 to 90% porosity and lightweight refractory fibers, plus organic and inorganic binding agents (Figure 4). Dispersant agents, pore-forming agents, high-temperature binders and plasticizers are typically added to produce the filter tube, allowing for excellent thermal resistance and thermal shock resistance. The fibers' structure enables a high internal surface area. The filters are most commonly supplied in 10-ft lengths and 6-in. diameters and typically weigh around 12.5 kg (27 lb). Figure 5 shows typical dimensions and structure. Some suppliers are investigating even longer lengths of 20 ft, allowing for fewer elements per box, resulting in even smaller footprints.

Low-density ceramic filters made up of ~3-µm dia. fibers are vacuum-formed into a rigid, tube-shaped fibrous filter element from a fiber slurry. The filter elements are installed as an alternative to conventional pulse-jet-cleaned fabric-filter elements. The filter elements are self-supported via an integral flange, as shown in Figure 6. The pressure drop across the filter boxes are held at around 4 in. H_2O(g) when in a clean condition.

Dry calcium- or sodium-based sorbents are injected into the fluegas upstream of the ceramic filter for SO_2 removal. Activated carbon or brominated activated carbon could also be injected to remove mercury. The fluegas is drawn through the filter tube wall by an induced-draft (ID) fan, where the collected particulate matter will build up as a cake on the outside of the tube (Figure 7). NOx is removed by catalytic reduction with injected ammonia or urea to form nitrogen and water. The catalyst is embedded within the filter walls. The clean fluegas then passes up the tube into the plenum. The cake is periodically cleaned from the filter walls inline using standard pulse-jet methods. Optimum pulse-jet frequency and pressure improve NOx reduction.

The ceramic filters are spray-embedded and dried with a catalyst slurry to facilitate reactions to remove NOx. The catalytic filter element consists mostly of Al_2O_3, SiO_3, TiO_2, V_2O_5 and WO_3. The micrometer-sized catalyst particles are distributed across the entire wall thickness using automatic equipment, thus creating a large, stable

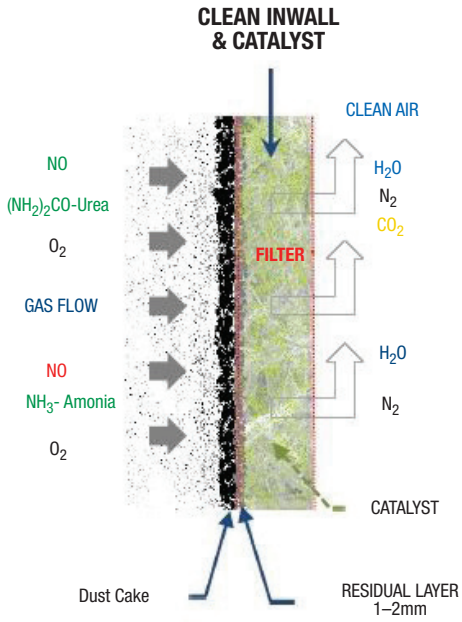


FIGURE 7. Particulate matter is removed from fluegas and collected inside the filter tube wall, while NOx is catalytically reduced using injected ammonia or urea. Sorbents injected upstream of the filter inlet mitigate SOx content

catalytic surface area. The catalyst particles' microporous structure and small size partially account for the increased reactivity at lower temperatures. To ensure the effectiveness of the catalytic particles, raw material inspection is crucial, as is robust sampling to check the catalytic activity after embedding.

CCF systems have a small footprint and are simple to operate. They could replace an existing ESP and eliminate the need for a separate SCR unit. Therefore, they can be retrofitted into industrial plants where there is not enough space to fit a conventional SCR unit.

The modular design of the boxed-housing units allows filters to be configured to handle large gas-flow volumes. The systems can be designed so that a single box can be taken offline if required, and the remaining two or more boxes continue to operate at a slightly higher pressure without interruption of the process itself and with no appreciable change in emissions.

No water is consumed in the process, and no wastewater is produced. However, the produced flyash residue requires disposal. Disposal of catalytic ceramic filters is required when they reach the end of their life. The catalyst lifetime has been found to be higher than in high-dust conventional SCR systems. The typical life of ceramic filters is five to ten years, with some installations running even longer. Generally, visual inspection for cracks, holes or missing corners can indicate whether a filter element is damaged or needs replacement. However, if the overall appearance of the filter element is normal, but the pressure drop increases and de-nitration efficiency decreases, this is an indicator that the catalyst is no longer effective and emissions requirements cannot be achieved.

Future work

Although they have been successfully deployed across many industrial sectors, CCF systems have not yet been used widely in high-dust applications, such as those found in coal-fired power plants and cement plants. Recently, more studies have been done with CCF technologies to evaluate their performance in coal-fired plants that have high ash or dust content. The research work in Ref. 2 covers a pilot study that used actual fluegas from coal combustion to remove SOx, HCl, NOx and dust in a single step. The project achieved 95% NOx removal, 85% SOx removal and 91% HCl removal. Also, the research found that ceramic candle filters were stable against high temperatures, as well as the presence of acid gas content and particulate matter. This work proposes that ceramic catalytic filters could provide a novel and feasible approach to multipollutant control in high-dust applications, such as coal-fired power plants. As additional installations are completed, more and more applications will find benefits in the use of CCF systems for air-pollution control. ■

Edited by Mary Page Bailey

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Addressing Problems in Filtration Processes

Careful attention to even the smallest details will help to prevent operational problems in filtration processes

Jose M. Sentmanat
Liquid Filtration Specialist, LLC

IN BRIEF

Filtration operations are widely used to achieve effective solid-liquid separations in the chemical process industries (CPI). Industrial filtration installations can involve a variety of components, including paper sheets, wire mesh, filter cloth and so on. If not properly specified and installed, even the smallest elements within a filtration system can lead to serious operational problems. This article outlines some of the typical problems encountered in industrial filtration processes, and how they can be rectified.

Filter paper problems

In filtration applications, loss of clarity in product streams occurs when the solids in the feed liquor bypass filter media and end up in the filtrate, contaminating the clean filtered liquor. The contamination resulting from the bypassed solids will cause problems, and if not corrected by a trap filter or recycling, it will allow unwanted solids into downstream equipment. To handle such contamination, the liquor must be filtered again either through a recycling step or by a second filter that ends up acting as the trap filter. This not only causes delays in the process, but also added expense if a trap filter must be installed. Often, loss of clarity occurs when the solids bypass filter-paper media through gaps resulting from improper placement of the filter paper. Filter paper sheets should be correctly placed on the filter plates to ensure that the filter paper is providing an effective seal in between the filter plates. Figure 1 illustrates the placement of the filter paper on the filter plate, and also some problematic situations that should be avoided.

FIGURE 2. Formation of tears in the wire mesh that covers the filter leaves may necessitate mesh replacement

Additional problems can arise when the filter paper becomes folded. Operators should pay close attention to ensure that the paper is placed flat on the filter plate. Furthermore, operational problems occur when the filter paper is crumpled, also causing contaminant bypass and loss of clarity.

To avoid issues, operators should also be aware that filter paper may swell up when the paper becomes wet with the liquid to be filtered. As it swells, the filter paper, if already compressed by the filter-plate compression rings, may start forming wrinkles. Once the filter cake starts forming within the filter paper's wrinkles, it will cause cracks in the filter cake and loss of clarity. This problem may be avoided by prewetting the filter paper as it is placed on the filter plate, thus allowing the filter paper to swell up before it is compressed in place by the filter-plate compression rings. The prewetting of the filter paper may

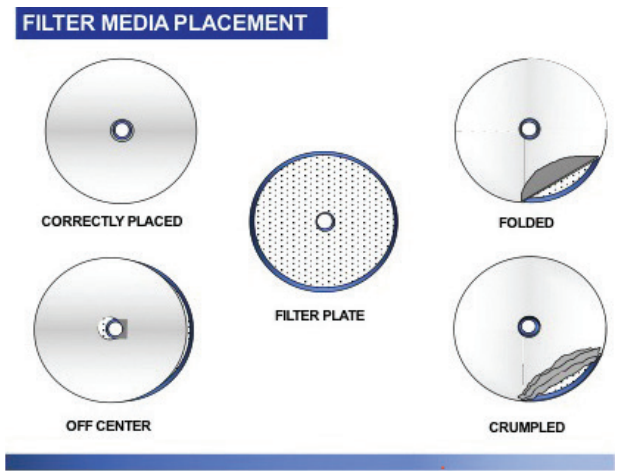

FIGURE 1. Filter paper must be properly placed on the filter plate to ensure trouble-free operation. Improper placement can lead to loss of clarity and other problems

FIGURE 3. Small pinholes in wire mesh can eventually form larger holes and result in loss of clarity

be done with either the liquid to be filtered or a compatible liquid, such as water.

Sometimes, if air gets trapped in the filter plate during the initial filling of the filter, it will start to push up on the filter paper, causing bubbles to form on the wet filter paper. Depending on the strength of the filter paper, the wet bubble may burst, causing a tear on the paper and consequently, loss of clarity. Conversely, the bubble in the wet filter paper may flatten as the pressure builds up during filtration. This phenomenon causes the filter cake formed on the bubbled paper to flatten and the filter cake to crack, allowing impurities to pass through the cracks, again leading to loss of clarity. This problem may be avoided by slowly filling the filter, allowing the air inside the filter plate to properly vent off through the air vent during filling.

Issues with tearing

Tears on the filter cloth bags can be another source of operational issues. Sometimes, operators may be a bit careless and drag the cloth-covered filter leaf on the floor, causing the cloth on the corners or edges to tear. Care must be taken when removing the filter leaves from shipping crates or from storage racks to avoid the filter leaf being dragged or dropped on the floor or other hard surfaces. These tears will cause loss of clarity. Small tears or holes may be patched up with silicone sealant, or another sealant that is compatible with the process liquid.

The wire mesh covering filter leaves can also be vulnerable to tearing (Figure 2). Again, due to carelessness, the wire mesh on the filter leaves may develop small pinholes or tears. Due to the abrasiveness of the filter aids, a small pinhole (Figure 3) may wear into a larger hole that also causes loss of clarity. Small pinholes may be patched with a compatible sealant. Larger tears may be patched by soldering the tear or by placing a small piece of wire mesh over the hole to secure it in place. Care must be taken not to use too much soldering because the excess solder material may build up under the wire mesh, which will cause bumps on the mesh. These bumps will result in additional problems, especially if the filter cake has to be scraped off of the wire mesh. This will cause even more tears. Filter leaves with tears on the wire mesh should be re-covered with new wire mesh or eventually replaced with new filter leaves.

FIGURE 4. Filter leaves can become overwhelmed by excessive solids volumes

Solids buildup and leaf damage

Once a filter is in operation, an excessive amount of filter cake can be produced during filtration and the filter leaves can become buried under such a large volume (Figure 4). In order to discharge the filter cake, the filter must be opened and the filter operator must remove the excess filter cake with a shovel to be able to reach the filter leaves. Figure 5 shows an opened filter with an overload of filter cake. When the filter leaves are buried by an excessive solids load, it prevents the self-cleaning feature of the filter to not function as designed. The excess volume of solids will prevent the internal spray system of the filter from properly washing the solids off of the filter internals. In the case of a filter with dry cake discharge, it will prevent the filter cake mechanism from working as designed, even possibly damaging the filter internals if the excessive solids volume has caused bridging. Bridging is a phenomenon where the filter cakes are touching and may not be properly discharged from the filter leaves. This problem forces the operators to open the filter to dig out the filter leaves from the solids, which may eventually cause damage to the filter leaves.

FIGURE 5. When filter leaves become buried by solids buildup, the filter must be opened for manual cleaning

Other issues that can lead to filter leaves becoming overwhelmed by plugged solids include: improper precoat to protect the wire mesh; not correctly discharging the filter cake; and improper cleaning of the filter.

Plugging causes the filter leaves to have spots that are blinded by solids buildup inside the filter leaves. If the filter continues to be used without properly cleaning the filter leaves, the filter cake will build only in areas that are not plugged up, as shown in Figure 6.

Operating with filter leaves that are in poor condition leads to many filtration problems, including ineffective filter cake release when cleaning the filter, loss of clarity and the overall deterioration of the filtration process. Figure 7 shows filter leaves that are very dirty and have damaged wire mesh.

Design, testing and validation

When a filter does not perform as expected, it is an indication to go back and look into the laboratory testing that was done to determine the filter application. For example, preliminary filter testing was done using a particular limestone from Texas to produce calcium chloride by reacting the limestone with hydrochloric acid. Once the plant was built and the filter was sized based on the laboratory test results, the plant decided to buy the limestone from a different source that had different components and impurities. When used in the plant, this mismatched feedstock caused problems with the operation of the filter, including the presence of additional solids in the reaction step and shorter filter cycles. An additional prefiltration treatment was introduced in order to minimize the load on the filter.

Sometimes, filter installations are built without any provisions for what is actually required to operate the filter properly. Such is the case of an installation for two filters with dry cake discharge. Once the filters were started up, it was found that there was not enough compressed-air supply to dry the filter cake. The automatic sequence of the filters had to be reprogrammed to allow a step to build up the air pressure in the filter to provide sufficient air volume to blow through the filter cake to dry the cake so that it could be released from the filter leaves. The filter-cake drying step was reprogrammed to let the air pressure build up with the filter outlet valve partially closed for some air to blow through the filter cake at 10 psi(g). This would prevent the filter cake from falling off

FIGURE 6. Filter leaves that are plugged with solids can experience uneven, inefficient filter cake formation

FIGURE 7. Filtration processes operating with damaged or dirty filter leaves will experience poor performance

the filter leaves and also allow air to build up inside the filter tank to a sufficient volume up to 50 psi(g) to quickly blow through the filter cake down to 10 psi(g). This step was repeated up to three times prior to discharging the filter cake with an air vibrator.

Auxiliary equipment

When selecting the auxiliary equipment or other components around the filter, care must be taken that the correct devices and materials of construction are selected to avoid possible malfunction and equipment performance problems. Although not directly related to the operation of the filters, ancillary components can impact filtration performance. For instance, a caustic plant experienced some serious operating problems when the air operators on the caustic filters' automatic process valves were supplied with aluminum mounts. The engineers that selected the automatic valves installed on the filters did not take into consideration that the caustic environment corroded the aluminum mounts, causing them to fail at the startup of the plant. The valves had to be operated manually until the valve operators were changed. When selecting equipment and mounting hardware in a caustic or corrosive environment, care and consideration must be given to select equipment and materials that will perform well in the corrosive environment. ■

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Operational Best Practices for Rotary Dryers

To maximize the service life and reliability of rotary dryers for solid materials, adhere to this set of practices

Shane Le Capitaine and Carrie Carlson
FEECO International

Rotary dryers have a well-deserved reputation for reliability, often providing decades of trouble-free operation in solids-handling processes. As with any type of process equipment, however, the reliability of a rotary dryer and its ability to consistently dry bulk solids hinges on proper operation and maintenance of the unit (Figure 1). This article covers best practices for rotary-dryer operation that will help to maximize the service life and reliability of the rotary dryer, while maintaining product integrity in industrial settings.

FIGURE 1. Rotary dryers like the one shown here, can be highly reliable when properly operated and maintained

Maintain a consistent feed

Rotary dryers are known for their tolerance to variation in feedstock conditions, such as particle size and moisture content. And while the tolerance for feedstock variation is real, the best results are still achieved by maintaining a feedstock that is as uniform as possible in all aspects. The more uniform the material going into the dryer, the more uniform the material will be coming out.

Operators struggling with product consistency issues often find that a large variance in feedstock conditions is to blame. In some settings, maintaining a uniform feedstock for a dryer may not be possible, but options do exist for minimizing excessive variation. One way to improve the uniformity of feedstock going to the dryer is to use a technique called "backmixing," which is achieved by mixing finished (dried) product with the raw feedstock before it enters the dryer (Figure 2). This evens out the overall moisture content of the material entering the dryer.

A more efficient way to manage variation is to eliminate it from the source material. This may involve a change in vendor specifications (or even a change in vendors), adding a pre-conditioning system, or making improvements in the process upstream of the dryer. In many cases, a process audit will reveal that by optimizing the performance of equipment upstream of the dryer, variation can largely be mitigated.

Never run empty with heat

One rule all operators and maintenance personnel should understand is to never run the dryer empty with heat. When the drum runs empty, there is no material to absorb the heat and protect the dryer. Similarly, the burner should never be left running while the dryer is not rotating.

Running the dryer empty or without rotation in the presence of heat has the potential to cause warping or deflection of the drum shell as a result of uneven heat distribution. A drum that is heated without rotation will result in localized heating, which causes the drum to sag.

If the temperature of the shell is allowed to exceed the yield strength of the material of construction, deformation of the shell will be permanent. In most cases where deflection has been allowed to occur, total shell replacement has been necessary.

Deflection causes additional problems where refractory material is employed, because the refractory will experience heat stress at a different rate than the shell, causing cracks or breaks in the refractory.

Minimize buildup

Depending on the material being dried and the design of the rotary dryer, buildup of material inside the drum can become an issue. Minimizing the amount of buildup that is allowed to occur is critical to the drum's longevity and efficiency.

Buildup in the dryer is problematic for a number of reasons. First, it reduces the overall efficiency of the drying process and often results in off-specification material. Buildup also has the potential to cause clumps of material that eventually break away from the dryer wall. When this happens, it can damage both the interior of the dryer and the flights (material lifters; described below), as well as the discharge breeching (where the product exits the dryer). Buildup that does not break away can pose a risk of fire for some materials. If the material is corrosive, buildup promotes

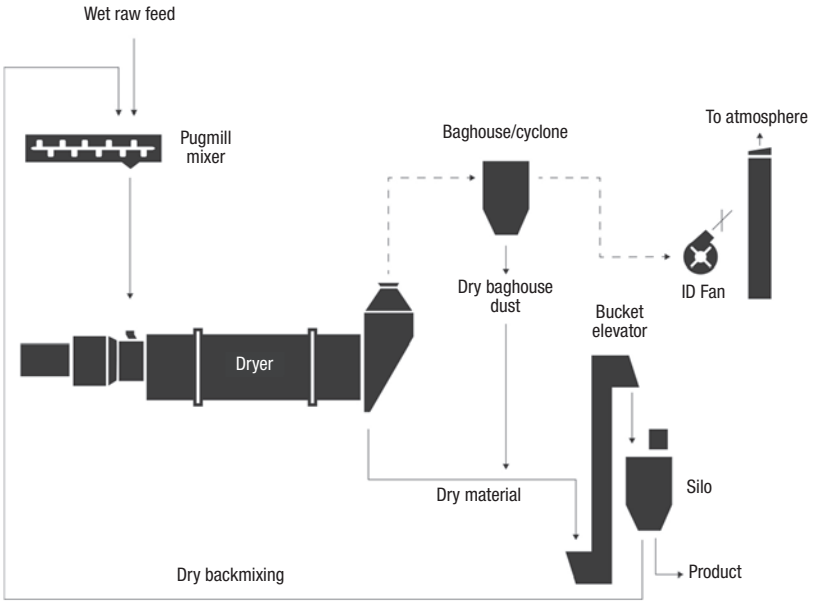

FIGURE 2. The diagram illustrates a common backmixing setup to improve the uniformity of the feedstock

excessive corrosive wear on the dryer walls and flights.

Several techniques exist for minimizing the potential for buildup in the dryer. Knockers, affixed to the drum's exterior, are one effective solution and work by "knocking" the drum (on a wear plate) to dislodge any buildup on the interior as the drum rotates.

Another option is to utilize a "bald" section (an area of the dryer without lifters) and use less aggressive lifters at the dryer inlet to avoid sticking.

Screw conveyors, which "throw" material into the dryer, can also help to minimize buildup by breaking up any clumps.

Keep seals in good condition

The seals on a rotary dryer, which connect the drum to its stationary housing, are critical in preventing ambient air from leaking into the system (Figure 3). Ambient air allowed to leak into the system reduces the dryer's temperature, which can have a variety of implications depending on the application and the severity of the leak. Common problems associated with leaking seals include increased fuel costs, reduced efficiency, lower throughput, and underdried product.

If these problems are observed, along with visible wear on seals, signs of material back spill, or abnormal auditory cues, it is often an indication that seal repair or replacement is necessary.

Inspections and maintenance

It may sound obvious, but regularly inspecting and maintaining a rotary dryer in accordance with the original equipment manufacturer's recommendations is the easiest — but yet most neglected — way to prolong the life and reliability of a dryer.

The constant rotation, longitudinal movement, changing heat stresses, and static and dynamic loads associated with rotary dryer operation all have a tendency to exacerbate and accelerate any problems the dryer may be experiencing. For this reason, it is critical to keep up on maintenance and regularly inspect the unit for any signs of a potential problem.

Regular inspections of the dryer, both internally and externally, allow operators to become familiar with the dryer and identify the onset of any problems early in their development. Ensuring all mechanical components are properly lubricated, resurfacing any wear on tires and trunnions, and routinely having the drum realigned are the foundational elements of keeping the dryer running reliably for years.

Utilize a control system

Control systems for rotary dryers range from basic to advanced and include everything in between. Most rotary dryers built today come with some form of control system to facilitate startup and shutdown and manage airflow and temperature.

Simple process control systems can be upgraded for intuitive automation that provides operators with a variety of data points. Control systems can even be programmed to help prevent potential problems before they occur by recognizing when key criteria fall out of specification and alerting the operator. In many cases, data points can be collected, trended and adjusted from the operator interface, or even a mobile device.

Whatever type of control system is in use, plant operators should be fully trained on the system, so they are able to maximize dryer performance and efficiency. Those operators working with older dryers not accompanied by a control system should consider investing in one, because the efficiency gains can be well worth the investment.

Consider a process audit

A rotary dryer may be underperforming for a variety of reasons — everything ranging from a problem with upstream equipment, to an unseen mechanical issue with the dryer. Whether the dryer is part of a larger bulk-solids processing operation or is a stand-alone drying operation, identifying the source of the problem can be a challenge. Operators struggling to meet specification requirements for products or rated capacity should consider a process audit.

A process audit evaluates the process conditions of the overall dryer system, as well as the surrounding process, identifying areas in need of attention and helping to pinpoint and resolve the origin of complex issues.

The expense of an underperforming dryer, be it in process downtime, lost production, off-specification product, or all of the above, quickly adds up. In addition, running a dryer out of specification for an extended period of time could poten-

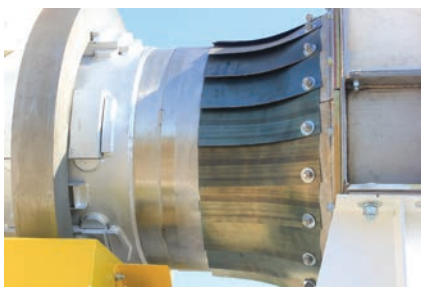

FIGURE 3. Shown here is a single-leaf seal

FIGURE 4. An interior view of the rotary dryer with flights is shown here

tially damage the unit. By opting for a process audit, the path to issue resolution is expedited.

Design considerations

In addition to operational considerations, there are several aspects of the dryer that should be considered during the initial design stages to ensure the dryer is suitable for the intended application and will provide long-term reliability.

Choose a dryer suited to its intended level of duty. One of the most common mistakes made in acquiring or designing a rotary dryer is the application of a one-size-fits-all design. The applications in which rotary dryers are employed vary substantially in their level of duty, and in the specific challenges presented by each job. As such, a one-size-fits-all solution almost always falls short. Dryers designed for use in the biomass industry, for example, would quickly fail under the demanding conditions of the mining industry.

For long-term reliable operation, dryers must be designed around the level of duty required by the intended application. This often means selecting different materials of construction, shell thicknesses, mechanical components, and seals for heavy-duty applications. The materials of construction, along with stringent quality standards in fabrication, are essential to acquiring a dryer that achieves a long lifetime and experiences minimal issues.

Optimize flight design. As with the overall design and construction of the rotary dryer, taking the time to optimize the flight design during the initial design process is also important in achieving an efficient and reliable drying solution (Figure 4).

Flights contribute significantly to drying efficiency, but only if they are designed to work with the unique characteristics of the material to be dried, in combination with drum rotation speed, slope, air velocity and retention time. Flights not designed around such criteria can reduce efficiency, drive up fuel costs, promote buildup, and lead to other problems.

Flights can be customized in both design and pattern, with many dryers incorporating multiple flight designs to accommodate the changes that occur in the material as it moves through the dryer.

Consider a combustion chamber. The combustion chamber is a static vessel affixed between the burner and drum that serves to house the combustion reaction (Figure 5). Rotary dryers are available with or without a combustion chamber. In some cases, they may be required to reach the precise drying conditions a given job demands, or to maintain product quality, while in other cases, they are not required, but could bring advantages to the system.

When the material being dried is heat-sensitive or could be damaged in some way by exposure to a flame, combustion chambers are effective at preventing flame contact. Preventing contact with the flame is also useful with materials that could form pollutants if exposed to a flame, which would increase the requirements for an exhaust-gas treatment system. For these reasons, potash dryers, for example, usually incorporate a combustion chamber, because potash will not only break down under exposure to a flame, resulting in inferior product, but will also produce undesirable pollutants if allowed to come into contact with the flame.

The use of a dilution air fan can also improve process control, by allowing the gas temperature entering the chamber to be more readily controlled. This improves overall efficiency and promotes a more complete combustion of the fuel.

Further, since there is no contact between the flame and the drum shell, dryers with a combustion chamber often last longer than their counterparts without combustion chambers.

Various combustion-chamber designs exist to optimize them for specific requirements. They are typically lined with refractory and may be single- or double-shelled. The chambers can also be inline, right-angled, or placed on a floor above or below with a 180-deg elbow.

FIGURE 5. The burner feeds into a combustion chamber attached to a rotary dryer

Operators struggling with either overdried product, product that has been deleteriously affected by the dryer, or problems with controlling the product outlet moisture, may benefit from the retrofit of a combustion chamber onto their existing dryer.

Concluding remarks

Rotary dryers are a substantial investment in any process. By following best practices in dryer operation and maintenance, that investment can be maximized for reliable long-term processing. The best practices mentioned here, along with choosing a dryer that is well suited to its intended application, including optimized flight design and the use of a combustion chamber where applicable, will help plant managers protect their investment and be confident that their dryer will provide reliable performance for the long term. ■

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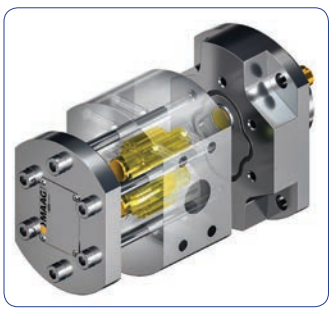

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Established in 1842, Ross is one of the world's oldest and largest manufacturers of process equipment, specializing in mixing, blending, drying and dispersion. **www.highshearmixers.com**

Premier Manufacturer of Custom Material Handling Equipment

Material Transfer has always held itself to a higher standard. That is how we have earned our reputation for the highest quality powder and bulk material handling equipment and systems in the market. Focused on serving the customer well, all of our products are built the way they should be built: robust in design, elegant in operation, simple to use and easy to maintain. This guiding principle has fueled our growth for more than 30 years.

MAJOR PRODUCTS:

Material Master™ Bulk Bag Conditioners – Quickly and safely return hardened materials to a free-flowing state. Our newly enhanced Material Master® Bulk Bag Conditioner leverages our patented design and unique feature set to bring customers the most advanced conditioning technologies at reduced price points. Flexible programming and touch-screen operator interfaces ensure consistent material conditioning, eliminate unnecessary labor, and reduce costs associated with bag breakage, production bottlenecks and compromised employee safety.

Material Master™ Bulk Bag Dischargers – Feature patented technology for clean, dust-tight discharge of your materials. Container & Drum Dischargers – Discharge any size container at heights to 40', dust-tight Lift & Seal System™ or open discharge. Patented Control-Link Rotation System™ for 180° rotation. Container and drum discharging systems are custom-designed to meet each customer's specification requirements.

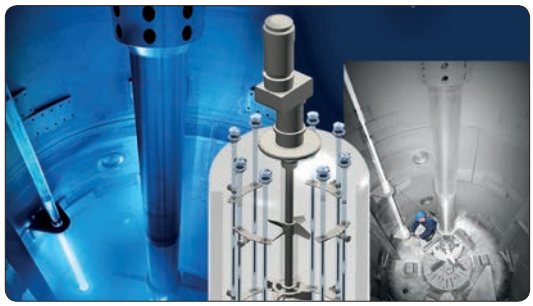
Material Master PowerFill® Bulk Bag Fillers – Material Transfer Bulk Bag Filling Stations offer a complete range of filling solutions, from a simple durable unit for low volume filling, to a highly sophisticated, automated system for high-volume production. The new PowerFill® Pro and PowerFill® Select Bulk Bag Fillers set the standard in reliability and high performance at price points that make the technology both more affordable and more valuable. Well-designed and solidly built with rich feature sets, they are easy to use and maintain. A broad range of options make custom-designing solutions for specific customer applications easier and more cost-effective than ever before.

These products are supported by the highest standards of excellence in service. Our service doesn't end when our products ship. From operator training to equipment evaluations, service contracts, remote equipment monitoring and more, our teams are focused on doing what's right for each of our customers: keeping their equipment up and running efficiently and safely.

www.materialtransfer.com

Optimize calibrations

Putting data to work by optimizing calibration intervals



Achieving the correct balance between too much calibration and too little is a challenge for anyone reliant on critical measurements. Many companies follow a static interval approach and calibrate once a year during scheduled downtimes. This fixed calibration interval selection is a typical illustration of established but outdated rules.

Ideally, calibration intervals should be chosen to reflect an acceptable risk that the measurement error has not drifted outside of an acceptable range. Considering common practice, this is seldom the case. Often calibration intervals are set to one year for the sake of convenience as it aligns well with annual planning cycles. However, calibration intervals should be optimized to find the best trade-off between cost and risk.

Using established existing statistical methods as a base, **Endress+Hauser** has developed an enhanced method for calibration interval optimization. With Calibration Interval Optimization Endress+Hauser has developed a service that delivers more than a calculated result. Significant interval changes are discussed, and all underlying assumptions validated together with the customers. Intervals are then included as one of a number of operational constraints including downtime availability to deliver a fully optimized calibration execution schedule. In the end, the customer benefits from an overall reduction of both cost and risk.

This scientific model has been proven across +22 billion calibrations and considers past calibration results to predict future behavior with the following main results:

- 67% of current calibration intervals could be significantly increased
- only 20% of instruments are set up with an optimal calibration interval
- time operating out of tolerance can be reduce by 46% compared to a static approach

Calibration Interval Optimization uses a proven scientific model to determine intervals between calibrations.

It includes:

- Determination of optimal calibration intervals using innovative methods
- Consultancy provided by metrology experts
- Alignment to, and application of intervals according to operational constraints

The benefits:

- Reduction of calibration costs due to extended calibration intervals
- Reduced out of tolerance risk as calibration intervals are reduced

www.endress.com

Jenike & Johanson Engineering Services

Jenike & Johanson, Inc. is the world's leading technology company for bulk material handling, processing, and storage. They deliver engineered solutions to achieve reliable powder and bulk solids flow based on proven theories and decades of project experience. With their skilled, highly technical team of experts and industry-leading innovations, they have successfully delivered bulk material engineering solutions for more than 55 years.

Bulk materials and their flow properties are at the core of all Jenike & Johanson's work. Every project (7,500+ to date) is truly unique. Clients are offered maximum flexibility in selecting services required to meet their bulk material handling needs. Jenike & Johanson does not follow the "one size fits all" concept – which can be a dangerous pitfall in engineering. Decisions made during the feasibility and engineering stages of a project are critically important for its success. If bulk solids systems are not engineered from the outset to handle the unique characteristics of the materials, process start-up time can be significantly delayed and design capacity may never be reached.

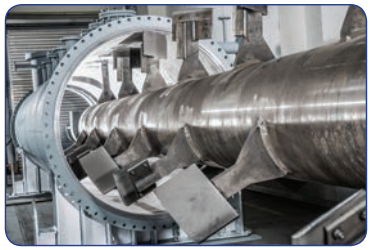
The engineers at Jenike & Johanson are renowned experts in the field of bulk material engineering. They are frequent keynote speakers at major industry events, routinely deliver informative webinars and customized courses, and publish thoughtful technical articles in top industry journals and publications – all this in order to provide clients with the latest insight on cutting-edge methodologies which make the powder and bulk solids handling aspect of the business run seamlessly.

The chemicals industry provides the building blocks for companies manufacturing paints, pigments, coatings, adhesives, resins, consumer products, and foods. 75% of all chemicals are handled in bulk solid form during manufacturing. When feeding powders to reactors or conveying wet cake from a centrifuge to a dryer, poor material flow can result in throughput limitations, non-uniform product, or dust emissions/spillage.

www.jenike.com

Viscous, pasty and sticky! How to dry?

Buss-SMS-Canzler's Combined Fluidization Technology Dryer (CFT)



Some wastes and products are hard to dry, because they undergo multiple changes of their state from liquid through high viscous, pasty, sticky, crust-forming and finally to solid state. Such feed materials can be handled by **Buss-SMS-Canzler's** Combined Fluidization Technology (CFT) Dryer. This type of dryer combines the advantages of fluidized bed drying with contact drying. The CFT dryer can handle liquid, semi-solid or solid feedstock in continuous operation because of its working principal.

The CFT works with a hot mechanically fluidized bed of solid product particles, which is fluidized mechanically by a rotor equipped with blades. The dryer is heated through the dryer shell and optional via the rotor shaft. The feed material is distributed to the fluidized hot particle bed. Because of the intensive contact of the bed particles and the feed material, the volatiles evaporate instantly. Thus no viscous, pasty or sticky phase exists inside the hot particle bed and no wet product gets into contact with the heated surfaces.

The working principle of the CFT allows processing in the solid phase at any time. Single train process solutions for large capacities can be realized with high flexibility in respect to capacity and composition of the feed material. CFT processing results in easy to handle solid products.

Typical applications of the CFT dryer are the drying of coal slurry, the treatment of industrial tar and paint sludges, the drying of yeast, the processing of crust forming salt solutions or slurries and the recovery of valuable material from waste streams like TDI from distillation residue. New applications can be tested in Buss-SMS-Canzler's test centre on a pilot scale plant.

www.sms-vt.com

Fully heated agitators

EKATO SYSTEMS refined the portfolio of the proven SOLIDMIX vacuum contact drying systems by means of fully heated agitators which results in significant shorter batch times and maximized discharge yields.

EKATO SOLIDMIX fully heated PARAVISC agitator

Quick and efficient drying of pasty to free-flowing products with high solid contents is always a challenge.

Drying at vacuum conditions allows the removing of solvents almost residue-free without a significant increase in product temperature.

With the help of over 85 years of experience in mixing technology, **EKATO** developed fully heated agitators for the SOLIDMIX product line, which set new standards compared to the usual heat exchange via the vessel wall. The moving surface of the heated agitators increases the overall contact and heat exchange area by more than 25%.

Production scale trials and applications show a 25% to 60% reduction in drying time:

The reduction of the drying time corresponds to the increase of the heat exchange surface. In most cases, the improved heat transfer of the moving stainless steel to the product as well as the constantly exchanged product around the agitator shortens the drying time immensely.

This is also valid for the heating and cooling of products where significant process time reductions can be reached as well.

Furthermore remarkable improvements in discharge yield and product quality are possible when using the heated agitators.

This is especially valid when drying products with strong adhesive properties and the tendency to stick to cool and wet surfaces. Material losses due to sticking material on agitator shafts after drying and lumps in the product caused by condensing fluids are reduced significantly.

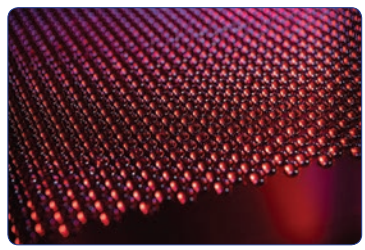
In combination with other heated surfaces e.g. a fully heated lid, drying processes of hard to dry materials are possible while reaching high discharge yields and homogeneous products.

Get in contact with our process experts in order to benefit of our technology.

www.ekato.com

Clean Processing for Laundry Product

Granulating high value perfume additive on IPCO Rotoform 4G



The chemical products that impart perfume to modern laundry products have a high value, and this means it is important that they are produced to precisely the right specifications. And as a product that comes into direct contact with the skin, laundry perfume needs to be produced under GMP-like conditions.

IPCO's Rotoform 4G meets both of these requirements and has become one of the most widely used systems for the production of laundry perfume.

The product is created by combining the chemical perfume with a carrier material, for example a fatty alcohol selected for its good solubility in water.

Once combined, the perfume additive is delivered to the Rotoform system in melt form. The Rotoform itself consists of a heated cylindrical stator and a perforated rotating shell that turns concentrically around the stator. Precisely metered drops of the product are deposited across the whole operating width of a continuously running stainless steel belt.

A system of baffles and internal nozzles built into the stator provides uniform pressure across the whole belt width, ensuring even flow through the holes of the rotary shell and uniformly sized pastilles from one edge of the belt to the other.

Heat released during cooling and solidification is transferred via the steel belt to cooling water sprayed underneath. This water is collected in tanks and returned to the water recooling system; at no stage does it come into contact with the product.

The Rotoform 4G process converts the chemical melt into solid pastilles of a defined and consistent size, a form that is free flowing and ideal for handling, storage and blending, a key requirement as the perfume is added to the detergent.

ipco.com/rotoform-granulation-systems/

GEA's Highly Versatile Industrial R55 Rotary Press

From nuclear fuel pellets, hard metals, catalysts, automotive parts and batteries to confectionery, almost anything is possible with the R55 rotary press

The R55 rotary press offers single-layer tablet and component production for a wide range of powder product processing applications at compression forces of up to 130 kN. The compression zone is completely sealed off from the technical zones for reduced maintenance. Complex shapes (maximum outer diameter of 60 mm and die filling depth of 55 mm) are easily accommodated.

The proprietary **GEA** punch holder design features a high-pressure head for long-lasting and trouble-free high force compaction and includes bearings on the side of the head for wear reduction. The punch tip in contact with the powder is interchangeable and can be made from a choice of materials for optimal wear resistance.

A pre-compression cam applies a force on the punch holder bearings for gentle deaeration of the powder for a longer time compared with a pre-compression roller, thereby reducing the risk of end-capping.

The large top and bottom compression rollers ensure perfectly symmetrical compression and traveling air compensators ensure the constant density of each tablet. As such, any tablet length variation is proportional to the weight variation. When constant tablet height is required, the compensators are preloaded with the maximum force allowed for punch safety and a strain gauge measures the compression force for tablet weight control. Real tablet density control can be performed using the Inline Density Control system.

A hold-down/hold-up system controls tablet expansion during the ejection process to prevent cracks in the tablets. And, thanks to the bearings on the punch holders, much higher ejection forces are possible compared with classical mushroom head punches. A customized star wheel allows for horizontal evacuation of tablets, thereby preventing soft tablets becoming damaged before sintering.

Supplied with either 12 or 16 stations, the R55 is a leap forward in industrial single output tableting. The latest available technologies, including servo drives, have been implemented for maximum flexibility, high precision tableting, enhanced operator safety and minimized maintenance. Double-sided industrial rotary presses are available for multi-layer production or higher output requirements.

Finally, customer service is much more than providing spare parts, it's about keeping customers happy and their plant performing well, years after the initial sale. That's fundamental to GEA.

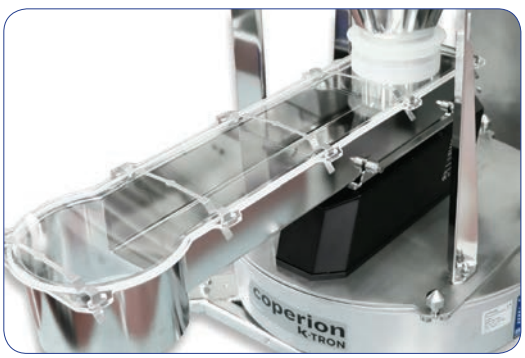
gea.com

New Vibratory Feeder Design Offers Improved Feeding Accuracy

There are a wide variety of feeding tools for solid bulk materials available on the market, some more successful than others. The screw feeder is generally the most utilized feeding tool, with different types of screws for different materials. New requests from the market for faster product changes, shorter cleaning times and less maintenance prompted **Coperion** K-Tron's research team to investigate other solutions. As screws can be limited in application, other feeding tools were evaluated and it was determined that vibratory feeders could be the ideal solution.

Traditionally, vibratory feeders were seldom used within the industry as they were often "inaccurate", tended to transfer vibrations to the environment, and limited tray length. Therefore, the first step in the research was a base study to understand the reasons behind these problems. With simulation technology and high-speed cameras, the team determined that the shock absorber design lay at the root of all three issues. The traditional rubber shock absorbers allow for rotational movement of the drive, which causes turbulence in the flow of the bulk material on the feeding tray. Based on this research, Coperion K-Tron developed a unique new flexible pendulum absorber design, which keeps the movement of the drive parallel to the desired direction of motion, eliminating rotational forces. As a result, material flow is consistent along the entire length of the tray with minimal pulsations, significantly improving feeding accuracy.

The Coperion K-Tron KCM-III feeder controller measures acceleration, displacement, load, current and temperature up to 25,000 times per second. The fast-acting controller then adjusts the vibratory drive signal to maintain clean sinusoidal displacement for optimal mass flow. This combination makes the new vibratory feeder more accurate than a screw feeder in many applications. The mechanical package is modular in design, accommodates custom tray configurations and lengths, and features an extended feed rate range of 1:500. A special quick-release clamp mechanism on the feeder tray allows for quick product changeover.



Another positive side effect of this new development is that the power consumption of this vibratory feeder is 20 times lower than that of a screw feeder. In comparison to a screw feeder, a vibratory feeder has no rotating parts, requiring less maintenance and fewer spare parts while also making it much easier to clean. Over the life of the feeder this results in a significant cost savings, especially when coupled with the lower power consumption.

www.coperion.com/feeders

Fast, homogenous mixing

The Bella XN fluidized zone mixer from Dynamic Air is a twin-shaft design that uses a "weightless" central fluidized area to provide thorough yet gentle mixing of dry products

The twin-shaft Bella mixer

The Bella fluidized-zone twin-shaft paddle mixer by **Dynamic Air** achieves fast, high-capacity, low-shear, precision mixing of either dry bulk solids or liquids with solids. Regardless of particle size, shape or density, materials are mixed with a fast, efficient, and gentle action, with typical mixing times of 15–30 s. A weightless zone created by low-speed counter-rotating paddles generates low friction without shear. This makes it ideal for abrasive products and fragile products that cannot tolerate rough handling. Even flakes or spray-dried bodies remain intact.

The Bella mixer consists of twin drums which have two counter-rotating agitators with specifically angled paddles. The paddles sweep the entire bottom of both mixer drums and yet allow the mixer to be started under full load (Figure 1). The material in the mixer moves in a horizontal counter-clockwise direction at the perimeter

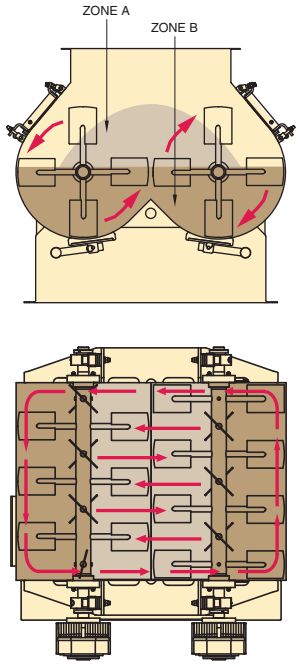


Figure 1 (right, top): In Zone A, fluidization promotes thorough mixing. Figure 2 (right): Material interchange between the two drums

while simultaneously moving both left and right in the center (Figure 2). The material in Zone B (Figure 1) is in its normal gravimetric state as it is being moved and dispersed. In Zone A, a weightless zone is created which effectively lifts the ingredients to an almost weightless state, allowing them to move freely and randomly, regardless of particle size and density. Thus the two zones' interaction becomes highly efficient as every particle moves rapidly to create a highly homogeneous mix, the key to the Bella mixer mixing technology for fast, precise mixing.

The Bella mixer is available in stainless steel and mild steel construction.

www.dynamicair.com/products/mixers.html

BEUMER Group: High-capacity packaging system handles films made of recycled material:

Complying with the law in packaging matters

The machine is easy and safe to operate.

Many packaging system owners who fix and package goods ready for dispatch by using stretch film for transshipment on pallets are unsettled: Since the beginning of 2019, the new packaging law has been in force. Its aim is to avoid waste and increase recycling. Therefore, many films will contain more recycled material in the future, which might considerably change their properties and also the handling.

For the film manufacturers who supply **BEUMER** Group, this is an economical solution to recycle their own production waste. The old material can be processed into regranulate and fed back into the production cycle. The utilisation of one's own regranulates permits the manufacturer to conserve resources, reduce emissions, minimise waste by recycling and avoid environmental impacts. Ideally, their quality can be even compared to that of new material. In this case, nothing changes for the packaging system.

The owners opt for the BEUMER stretch hood® A packaging system to protect the goods from dust and pests.

However, the film properties can considerably change due to the portion of recycled material. A film manufacturer relies simultaneously on high quality and less material. "The stretch films are therefore thinner but more efficient than conventional films," he says. Thus, the packaged products are secured in an optimum way and at the same time less material is used. The result is a higher production throughput and less exchange of film rolls at the machine. The BEUMER experts have thoroughly tested the film with their packaging system BEUMER stretch hood® A, which handles these thin films in an accurate and reliable way.

Together with the film manufacturers, the BEUMER experts have performed tests and analyses with various films in their in-house R&D centre. BEUMER has noticed that films with a high portion of recycled material behave like conventional plastic material during processing.

So everything is clear? BEUMER welcomes the new packaging law. After all, sustainability is part of their corporate philosophy. Thus, the users can continue to use the high-capacity packaging system to cover detergents, paint buckets, barrels or champagne boxes on pallets with a highly elastic stretch hood. The film fits very tightly, 'like a second skin', to the entire stack and thus ensures the necessary stability even with the new films they tested.

www.beumer.com

Handle virtually any bulk solid material

Flexicon stand-alone equipment and automated plant-wide systems convey, discharge, condition, fill, dump and weigh batch bulk materials dust-free

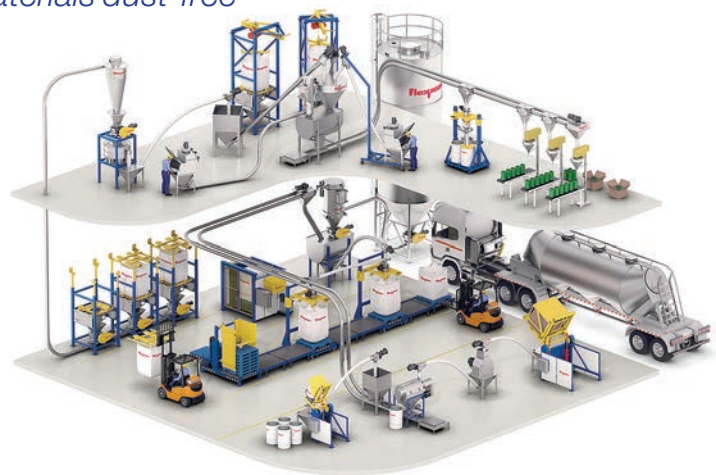
Flexicon engineers and manufactures a broad range of equipment that handles virtually any bulk material, from large pellets to sub-micron powders, including free-flowing and non-free-flowing products that pack, cake, plug, smear, fluidize, or separate.

Individual bulk handling equipment includes: flexible screw conveyors, tubular cable conveyors, pneumatic conveying systems, bulk bag dischargers, bulk bag conditioners, bulk bag fillers, bag dump stations, drum/box/container dumpers, and weigh batching/blending systems. Each of these product groups encompasses a broad range of models that can be custom engineered for specialized applications, and integrated with new or existing upstream and downstream processes and storage vessels.

All equipment is available to food, dairy, pharmaceutical and industrial standards.

For large-scale bulk handling projects, Flexicon's separate Project Engineering Division provides dedicated Project Managers and engineering teams on four continents to handle projects from concept to completion. Working with each customer's preferred engineering firm or directly with their in-house team, Flexicon adheres strictly to the customer's unique standards, documentation requirements and timelines through a single point of contact, eliminating the risk of coordinating multiple suppliers.

Flexicon's worldwide testing facilities simulate full-size customer equipment and systems, verify performance prior to fabrication, demonstrate newly constructed equipment for visiting customers, and study the performance of new designs.



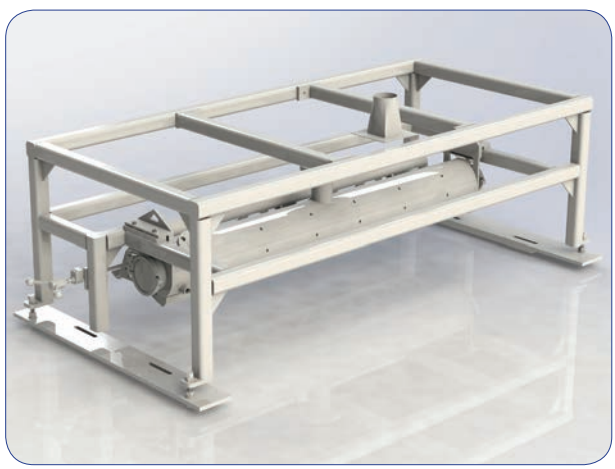
Flexicon offers stand-alone bulk handling equipment as well as plant-wide systems integrated with new or existing processes

The company recently doubled the size of its manufacturing facility and world headquarters in Bethlehem, PA, and also operates manufacturing facilities in Kent, United Kingdom; QLD, Australia; and Port Elizabeth, South Africa. **www.flexicon.com**

Process equipment – bernflow® new feeding device for flaking

Berndorf Band Group is the leading producer of steel belts and steel belt systems for numerous industries including the chemical sector. With operations in North America, South America, Europe, and Asia, the group consists of the parent company in Berndorf and its nine subsidiaries, partner companies and a worldwide service network. To ensure high-yield and high-quality productions in the chemical sector, Berndorf Band Group offers steel belts and steel belt coolers with pastillators or other infeed devices engineered and manufactured to customer specifications.

Besides corrosion resistant steel belts and different cooling systems a new feeding device was added to the process equipment portfolio of the group. The bernflow® feeding device is designed for a broad application range of products from medium to high viscosity. With the bernflow® the raw material is continuously fed in a sheet form to the steel belt surface. In addition, to the feeding device, the machine can be assembled with a breaker at the discharge end. With this option, the manufactured product sheet is controlled crushed into the required flake size. Matching to all feeding device designs of Berndorf Band Group, the bernflow® design focuses on service accessibility and simplicity for maintenance.



Further to the extension of the product portfolio, the group's subsidiary Berndorf Belt Technology USA has named Jeff Dallstream sales executive of the western region North America. With over 15 years industry experience he supports Berndorf's position as leader in steel belt production, belt system technologies and customer support. Dallstream is in charge for supporting the sales of process equipment of the worldwide group in North America and Canada.

For more information about the extensive portfolio of the group or to browse through the worldwide sales and service network, please visit **www.berndorfband-group.com**

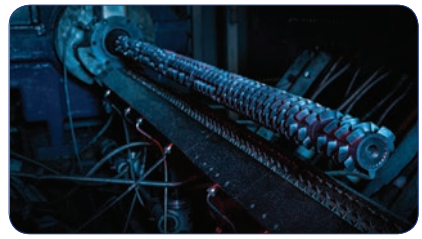
Rota-Cone® Blender

The **Paul O. Abbe** Rota-Cone® blender is the ideal choice for thorough and gentle blending of powders or crystalline products. Because this tumble blender has no shaft seals or agitator, cleaning is simplified and cross-contamination minimized. All internal surfaces the Rota-Cone® can be inspected from the single loading hatch.

Liquids can be added through the optional spray line and a pin agitator can be added to facilitate liquid dispersion, granulation or de-agglomeration. Loading can accomplish with our automated drum loading and discharging system. Controls including variable frequency drive and PLC can be supplied in NEMA-4X or NEMA-7&9 explosion-proof design. Available sizes range from 0.1 to 500 cubic feet working capacity.

www.pauloabbe.com

B&P Littleford's Innovative Compounding Technology



For more than a century, **B&P Littleford**'s industrial equipment has been helping customers make their manufacturing processes better, more efficient, and more profitable. B&P designs and builds a wide spectrum of mixing, drying, extruding, compounding, and centrifugal separation equipment for large- or small-scale manufacturing applications.

Their exclusive TriVolution Compounder (3 strokes per screw revolution) offers a dramatic shift in process performance while using less energy than competitive products. The design basis enables an easy transition for new owners as the unit retains the basic modularity of most familiar compounding extruders. This machine – like all of the B&P Littleford compounding equipment – is designed and built in Saginaw, MI. Full-service testing, parts, and rental equipment are readily available for the full line of products, as well.

Whether it is planning a new product, seeking to enhance production of a current product line, modifying a formula, trying to boost environmental performance, or simply need increased efficiency in production, B&P Littleford will customize an industrial machine solution to fit their customers' needs.

www.bplittleford.com

Hapman Advantages

Product Life and Longevity: Better Designs, Built Better

Hapman equipment is built to last, with outstanding engineering, fabrication and materials of construction. We draw on decades of proven engineering and field performance to ensure your Hapman product will stand up to your application.

- 98.9% success rate; only 1.1% warranty claims since 2014

Hapman equipment is still operating in the field after 35 years

Built for Serviceability: Ease of Maintenance

Our equipment is designed for fast, easy disassembly for cleaning and maintenance. You know what a difference that can make in your uptime.

- Since 2012, we have made 22 design improvements to maximize serviceability
- 12 of the Design Changes Made for Tool-Less Access

Accurate, Complete Documentation: Regularly Updated Information

Every Hapman unit comes with the information you need to run it right, including complete manuals and regular updates and service bulletins.

- Customized manuals with all Hapman equipment, including detailed drawings
- Hundreds of manual revisions/updates distributed every year
- Detailed reports for every service visit

Fast Access to Parts: 24/7 Support to Get You Back in Action Fast

We're standing by to get you the parts or service you need quickly, via toll-free phone or internet.

- Staffed 24 hours a day, seven days a week, 365 days per year
- Program in place to expedite parts orders
- $1.5 million worth of parts ready for immediate shipment

Staff Expertise: Broad Industry Expertise and A Deep Knowledge Base

Rely on Hapman for experience in all major bulk processing industries. We retain experienced engineers who publish regularly and professionally support our industry.

- Experience with over 2,700 distinct materials
- 12,000+ applications for 80+ international companies in 26 countries
- Over 7,300 Material Test Results on file
- Extensive thought capital; see 80+ articles in the "News and Knowledge" section of our web site.

www.hapman.com

Economic Indicators

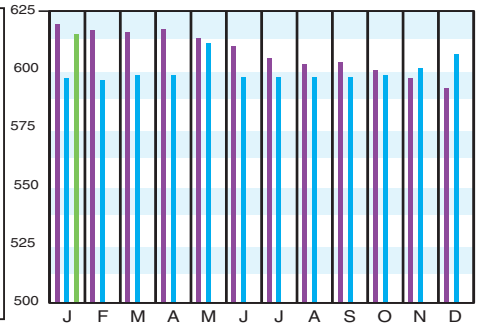
2019 2020 2021

Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	Jan. '21 Prelim.	Dec. '20 Final	Jan. '20 Final
CE Index	616.5	606.9	596.2
Equipment	751.5	737.3	724.1
Heat exchangers & tanks	637.2	621.4	618.8
Process machinery	746.7	737.7	721.7
Pipe, valves & fittings	1,012.4	998.7	957.3
Process instruments	439.8	433.4	419.1
Pumps & compressors	1,103.4	1,086.2	1,080.2
Electrical equipment	573.2	571.2	563.8
Structural supports & misc.	798.7	772.5	767.1
Construction labor	334.8	336.4	333.9
Buildings	635.0	621.0	588.2
Engineering & supervision	311.1	311.6	313.7

Annual Index:
2013 = 567.3
2014 = 576.1
2015 = 556.8
2016 = 541.7
2017 = 567.5
2018 = 603.1
2019 = 607.5
2020 = 596.2

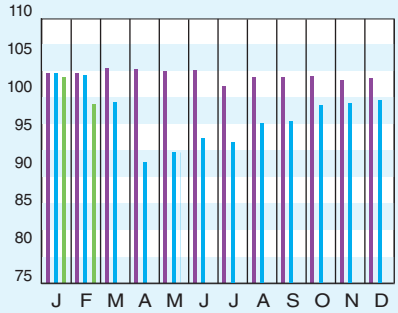


Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

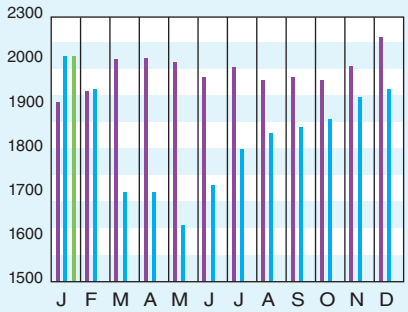
CURRENT BUSINESS INDICATORS

	LATEST	PREVIOUS	PREVIOUS	YEAR AGO
CPI output index (2012 = 100)	Feb. '21 = 97.4	Jan. '21 = 100.5	Dec. '20 = 100.5	Feb. '20 = 102.5
CPI value of output, $ billions	Jan. '21 = 2,000.5	Dec. '20 = 1,952.1	Nov. '20 = 1,895.0	Jan. '20 = 2,030.1
CPI operating rate, %	Feb. '21 = 72.9	Jan. '21 = 75.1	Dec. '20 = 75.1	Feb. '20 = 76.1
Producer prices, industrial chemicals (1982 = 100)	Feb. '21 = 260.7	Jan. '21 = 235.3	Dec. '20 = 235.3	Feb. '20 = 243.0
Industrial Production in Manufacturing (2012 =100)*	Feb. '21 = 100.7	Jan. '21 = 102.6	Dec. '20 = 102.6	Feb. '20 = 104.9
Hourly earnings index, chemical & allied products (1992 = 100)	Feb. '21 = 191.6	Jan. '21 = 194.3	Dec. '20 = 194.3	Feb. '20 = 186.2
Productivity index, chemicals & allied products (1992 = 100)	Feb. '21 = 97.5	Jan. '21 = 104.1	Dec. '20 = 104.1	Feb. '20 = 98.8

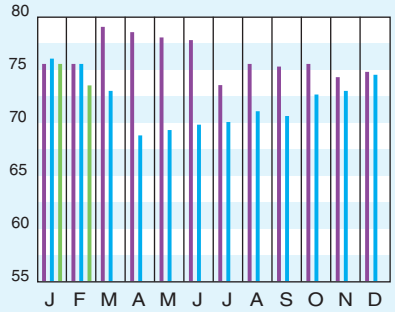
CPI OUTPUT INDEX (2000 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2000 to 2012
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index (CEPCI; top) for January 2021 (the most recent available) shows another significant increase from December 2020. The current value is the fourth consecutive monthly increase, and the second consecutive monthly increase of over five points. The uptick in the January preliminary CEPCI value was driven by increases in the Equipment and Buildings subindices. The Construction Labor and Engineering & Supervision subindices both saw small decreases. The current CEPCI value now sits at 3.4% higher than the corresponding value from January 2020. Meanwhile, the Current Business Indicators (middle) showed a lower CPI Output Index and Operating Rate for February.